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# Study of ONE-MAN LUNAR FLYING VECHICLE FINAL REPORT

## Volume V
## Preliminary Design and Specifications

Space Division
North American Rockwell

NASA CR 101922

SD 69-419-5

# STUDY OF ONE-MAN LUNAR FLYING VEHICLE
# FINAL REPORT

## VOLUME V
## PRELIMINARY DESIGN AND SPECIFICATIONS

Contract NAS9-9045

31 August 1969

# FOREWORD

This volume presents the preliminary design and specifications for the lunar flying system. This work was accomplished under the One-Man Lunar Flying Vehicle Contract (NAS9-9045), conducted by the North American Rockwell Space Division for the National Aeronautics and Space Administration Manned Spacecraft Center, Houston, Texas. Other volumes to this report are:

Volume 1. Summary
Volume 2. Mission Analysis
Volume 3. Subsystem Studies
Volume 4. Configuration Design
Volume 6. Training and Resources Plans

# TECHNICAL REPORT INDEX/ABSTRACT

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|---|---|
| | UNCLASSIFIED |

**TITLE OF DOCUMENT**

STUDY OF ONE-MAN LUNAR FLYING VEHICLE - FINAL REPORT: VOLUME 1 - SUMMARY; VOLUME 2 - MISSION ANALYSIS; VOLUME 3 - SUBSYSTEM STUDIES; VOLUME 4 - CONFIGURATION DESIGN; VOLUME 5 - PRELIMINARY DESIGN AND SPECIFICATIONS; VOLUME 6 - TRAINING AND RESOURCES PLANS

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**DESCRIPTIVE TERMS**

*ONE-MAN LUNAR FLYING VEHICLE, *CONTROL SYSTEMS, *PROPULSION SYSTEMS, *TRAJECTORIES, *DESIGN, *TRAINING, *RESOURCES, *MISSION ANALYSIS


**ABSTRACT**

THE PRIMARY OBJECTIVES OF THIS STUDY WERE TO OPTIMIZE THE DESIGN AND TO DEVELOP SYSTEM SPECIFICATIONS OF THE LUNAR FLYING VEHICLE. THE SCOPE ENCOMPASSED PARAMETRIC INVESTIGATIONS, CONCEPT GENERATION, AND EVALUATION EFFORT FOR THE DEFINITION OF A RECOMMENDED CONCEPT; PRODUCTION OF A PRELIMINARY DESIGN AND DEVELOPMENT OF SYSTEMS SPECIFICATIONS OF THE RECOMMENDED CONCEPT; AND DEFINITION OF RESOURCES AND CREW TRAINING PLANS. IN ADDITION TO GENERATION OF THE LFV DESIGN, THE SCOPE OF THE STUDY INCLUDED LUNAR MODULE INTEGRATION, FLIGHT SUIT INTERFACE STUDIES, AND DEFINITION OF GROUND SUPPORT EQUIPMENT FOR EARTH AND LUNAR OPERATIONS.

AS A RESULT OF PARAMETRIC STUDIES CONDUCTED DURING THE FIRST PHASE OF THIS EFFORT, A CONCEPT WAS SELECTED WHICH HAS THE FOLLOWING CHARACTERISTICS: (1) STABILITY-AUGMENTED CONTROL, (2) FOUR GIMBALED ENGINES WHICH ARE CLUSTERED BENEATH THE VEHICLE, (3) A SEATED PILOT POSITION, AND (4) AN INTEGRAL X-FRAME LANDING GEAR WITH 6 HYDRAULIC ATTENUATORS. THIS VEHICLE IS CAPABLE OF CARRYING A 370-LB PAYLOAD IN ADDITION TO THE PILOT. THE DRY WEIGHT OF THE VEHICLE IS 304 LB. WHEN LOADED WITH 300 POUNDS OF LM DESCENT STAGE PROPELLANTS, THE VEHICLE CAN OPERATE WITHIN A 4.6 NAUTICAL MILE RADIUS WITH NO PAYLOAD.

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# ILLUSTRATIONS

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# LUNAR FLYING SYSTEM SPECIFICATION

## 1. SCOPE.

1.1 Scope. This specification establishes the performance, design, development, and test requirements for a Lunar Flying System to be utilized in lunar mission surface exploration activity. The system specification, in conjunction with the end item specifications of the system elements, form the documentation establishing the system technical requirements, test requirements, and configuration description.

1.2 System Description. The Lunar flying system is composed of the following elements:

Lunar flying vehicle (LFV)
Lunar support equipment (LSE)
Development test articles
Training articles

The general configuration of the lunar flying system, the vehicle, and its lunar support equipment are shown in the accompanying preliminary design drawings.

## 2. APPLICABLE DOCUMENTS

2.1 Applicability. The following documents, of exact issue shown, form a part of this specification to the extent specified herein. In the event of conflict between documents referenced here and other detail contents of Sections 3, 4, and 5, the detail requirements of Sections 3, 4, and 5 shall be considered a superseding requirement.

SPECIFICATIONS

Military

| | |
|---|---|
| MIL-D-1000<br>1 March 1965 | Drawings, Engineering, and Associated Lists |

Federal

| | |
|---|---|
| NASA/MSC EP5/C<br>7 August 1967 | U.S. Government memorandum, Utilization of LM Descent Stage Residue Propellants for Extended Lunar Stays |

STANDARDS

Military

| | |
|---|---|
| MIL-STD-461<br>31 July 1967 | Electromagnetic Interference Characteristics, Requirements |
| MIL-STD-143<br>15 June 1969 | Specifications and Standards, Order of Precedence for the Selection of |
| MIL-STD-454<br>5 Jan 1965 | Standard General Requirements for Electronic Equipment |
| MIL-STD-721<br>2 Aug 1962 | Definition of Terms for Reliability Engineering |
| MIL-STD-681<br>6 Feb 1967 | Identification Coding and Application of Hookup and Lead Wire |
| MIL-STD-1247<br>12 March 1962 | Identification of Pipe, Hose, and Tube Lines for Aircraft, Missiles, Space Vehicles, and Associated Support Equipment and Facilities |

National Aeronautics and Space Administration

NASA MSC Design Standards Bulletin DS-21A, Meteoroid Environment - Near Earth and Cislunar

Annex C to NASA RFP for Lunar Roving Vehicle Design Study, 1969 - Natural Environment and Surface Design Criteria

PUBLICATIONS

Grumman Aircraft Engineering Corp., Report ARP 325-7B, (26 September 1968), Extended Lunar Module/Lunar Roving Vehicle Interface Definition

3. REQUIREMENTS. This specification shall provide the baseline for the lunar flying system and its supporting associate system elements. The lunar flying system interfaces with:

a. The lunar module (LM)

b. The flight suit of the astronauts

c. The portable life support system (PLSS)

d. GFE LFV Payloads

3.1 Performance. The lunar flying system shall provide vehicular conveyance of an astronaut pilot and payloads for five sorties during a lunar dawn mission.

3.1.1 Performance Characteristics. The lunar flying system shall provide a vehicle to transport one crew member and payloads up to 370 pounds to sites on the lunar surface for exploration remote from the LM.

3.1.1.1 Operational. The lunar flying system shall support the vehicle flying on the moon's surface in accordance with lunar flying vehicle flight profile defined in Figures 1, 2, 3 and Table 1.

3.1.1.1.1 Employment. The lunar flying vehicle shall utilize residual propellants in the LM descent stage. The nominal design reference available quantity shall be 1000 pounds at a mixture ratio of 1:5.

Table 1. Lunar Staytime Events

| Starting Time | Event | | Duration |
|---|---|---|---|
| :00 | Extended lunar module (ELM) touchdown on lunar surface; surface temperature -50 F | | - |
| :00 | Checkout and activation of ELM for lunar stay | | 2:00 |
| | Postlanding checkout | :30 | |
| | Launch simulation | 1:30 | |
| 2:00 | Science conference with earth | | :30 |
| 2:30 | Personal maintenance (lunch) | | 1:00 |

Table 1. Lunar Staytime Events (Cont)

| Starting Time | Event | | Duration |
|---|---|---|---|
| 3:30 | Preparation for EVA | | :30 |
| | Don and check out PLSS | :25 | |
| | Dump cabin pressure and egress | :05 | |
| 4:00 | EVA 1 and 2; surface temperature -20F | | 3:00 |
| | ELM inspection | :20 | |
| | Erection of solar array | :20 | |
| | Erection of radiator | :30 | |
| | Erection of antenna | :20 | |
| | Dismount LFV's (1) | :10 | |
| | Assemble LFV's (1); mount science equipment on LFV 1 | :05 | |
| | Set up landing mat and aids - 50 feet from ELM | :10 | |
| | Move LFV 1 to mat 1 | :05 | |
| | Check out LFV 1 (electronics/controls) | :10 | |
| | Deploy fuel and oxidizer hoses | :10 | |
| | Dismount and assemble advanced ALSEP | :40 | |
| 7:00 | Ingress to ELM and hook up ELM-ECS | | :10 |
| 7:10 | Repressurize ELM and doff pressure suits | | :20 |
| 7:30 | Personal maintenance (supper) | | 1:00 |
| 8:30 | Housekeeping and maintenance check | | 1:00 |
| 9:30 | Sleep, rest | | 7:00 |
| 16:30 | Personal maintenance (breakfast) | | 1:00 |
| 17:30 | Preparation for EVA | | 1:00 |
| | Don and check out pressure suits | :30 | |
| | Don and check out PLSS | :25 | |
| | Dump cabin pressure and egress | :05 | |
| 18:30 | EVA 3 and 4; surface temperature 45 F | | 3:00 |
| | Scientist astronaut 1 (SA 1) | | |
| | Fuel LFV on mat and mount helium tank | :25 | |
| | Check out LFV | :10 | |

Table 1. Lunar Staytime Events (Cont)

| Starting Time | Event | | Duration |
|---|---|---|---|
| | Flight out - 0.5 n mi qualification flight | :03 | |
| | Postlanding checkout | :05 | |
| | Deploy launching mat | :10 | |
| | Local exploration | :30 | |
| | Preflight checkout | :05 | |
| | Flight back - 0.5 n mi | :02 | |
| | Postlanding checkout | :05 | |
| | Monitor SA 2 flight | :30 | |
| | Complete setting up advanced ALSEP | :55 | |
| | Scientist astronaut 2 (SA 2) | | |
| | Start setting up advanced ALSEP | :60 | |
| | Monitor SA 1 flight | :30 | |
| | LFV qualification flight, same as above | :60 | |
| | Refuel LFV, deploy thermal blanket | :30 | |
| 21:30 | Ingress to ELM and hook up ELM-ECS | | :10 |
| 21:40 | Repressurize ELM and doff pressure suits | | :20 |
| 22:00 | Personal maintenance (lunch) | | 1:00 |
| 23:00 | Science conference with earth | | 1:00 |
| 24:00 | Preparation for EVA (same as hour 17:30) | | 1:00 |
| 25:00 | EVA 5 - scientist astronaut 1, surface temperature 85F | | 3:00 |
| | Replace helium tanks and batteries | :10 | |
| | Check out LFV | :10 | |
| | Flight out - 7 n mi | :04 | |
| | Postlanding checkout | :05 | |
| | Deploy launching mat | :10 | |
| | Local exploration | 1:37 | |
| | Preflight checkout | :05 | |
| | Flight back - 7 n mi | :04 | |
| | Postlanding checkout | :05 | |
| | Refuel LFV - deploy thermal blanket | :30 | |
| | Scientist astronaut 2 monitors | 3:00 | |

Table 1. Lunar Staytime Events (Cont)

| Starting Time | Event | Duration |
|---|---|---|
| 28:00 | Ingress to ELM and hook up ELM-ECS | :10 |
| 28:10 | Repressurize ELM and doff pressure suits | :20 |
| 28:30 | Personal maintenance (supper) | 1:00 |
| 29:30 | Review results of flight with earth scientists | 1:00 |
| 30:30 | Housekeeping and maintenance check | 1:00 |
| 31:30 | Sleep, rest | 8:00 |
| 39:30 | Personal maintenance (breakfast) | 1:00 |
| 40:30 | Preparation for EVA (same as hour 17:30) | 1:00 |
| 41:30 | EVA 6 - scientist astronaut 2, surface temperature 130°F<br>Same as EVA 5<br>Scientist astronaut 1 monitors | 3:00 |
| 44:30 | Ingress to ELM and hook up ELM-ECS | :10 |
| 44:40 | Repressurize ELM and doff pressure suits | :20 |
| 45:00 | Personal maintenance (lunch) | 1:00 |
| 46:00 | Science conference with earth | 1:00 |
| 47:00 | Preparation for EVA (same as hour 17:30) | 1:00 |
| 48:00 | EVA 7 - scientist astronaut 1; surface temperature 150°F<br>Same as EVA 5<br>Scientist astronaut 2 monitors | 3:00 |
| 51:00 | Ingress to ELM and hook up ELM-ECS | :10 |
| 51:10 | Repressurize ELM and doff pressure suits | :20 |
| 51:30 | Personal maintenance (supper) | 1:00 |

Table 1. Lunar Staytime Events (Cont)

| Starting Time | Event | Duration |
|---|---|---|
| 52:30 | Housekeeping and maintenance check | 1:00 |
| 53:30 | Sleep, rest | 8:00 |
| 61:30 | Personal maintenance (breakfast) | 1:00 |
| 62:30 | Preparation for final EVA's (same as hour 17:30) | 1:00 |
| 63:30 | EVA 8 and 9; surface temperature 165 F<br>Sample selection<br>Sample storage<br>Check ALSEP<br>Check out ELM ascent stage | 3:00 |
| 66:30 | Ingress to ELM and hook up ELM-ECS | :10 |
| 66:40 | Repressurize ELM | :05 |
| 66:45 | Personal maintenance (lunch) | 1:00 |
| 67:45 | Prelaunch countdown and checkout | 3:00 |
| 70:45 | Lift off - surface temperature 175 F | - |

3.1.1.1.2 LM Integration. Integration of the lunar flying system flight elements with the lunar module shall be accomplished prior to mating of the (spacecraft lunar module adapter) SLA and LM (approximately 86 working days prior to launch). No access to the lunar flying system elements will be available after SLA-LM mating.

3.1.1.2 Logistics. The lunar flying vehicle shall be designed for manned operation with full utilization of crew capabilities and minimum utilization of automatic subsystems.

3.1.1.2.1 Special Features. One crew member shall be able to remove the flying vehicle from the LM and prepare it for flight. In addition, the vehicle shall be flown by one crew member with no passenger.

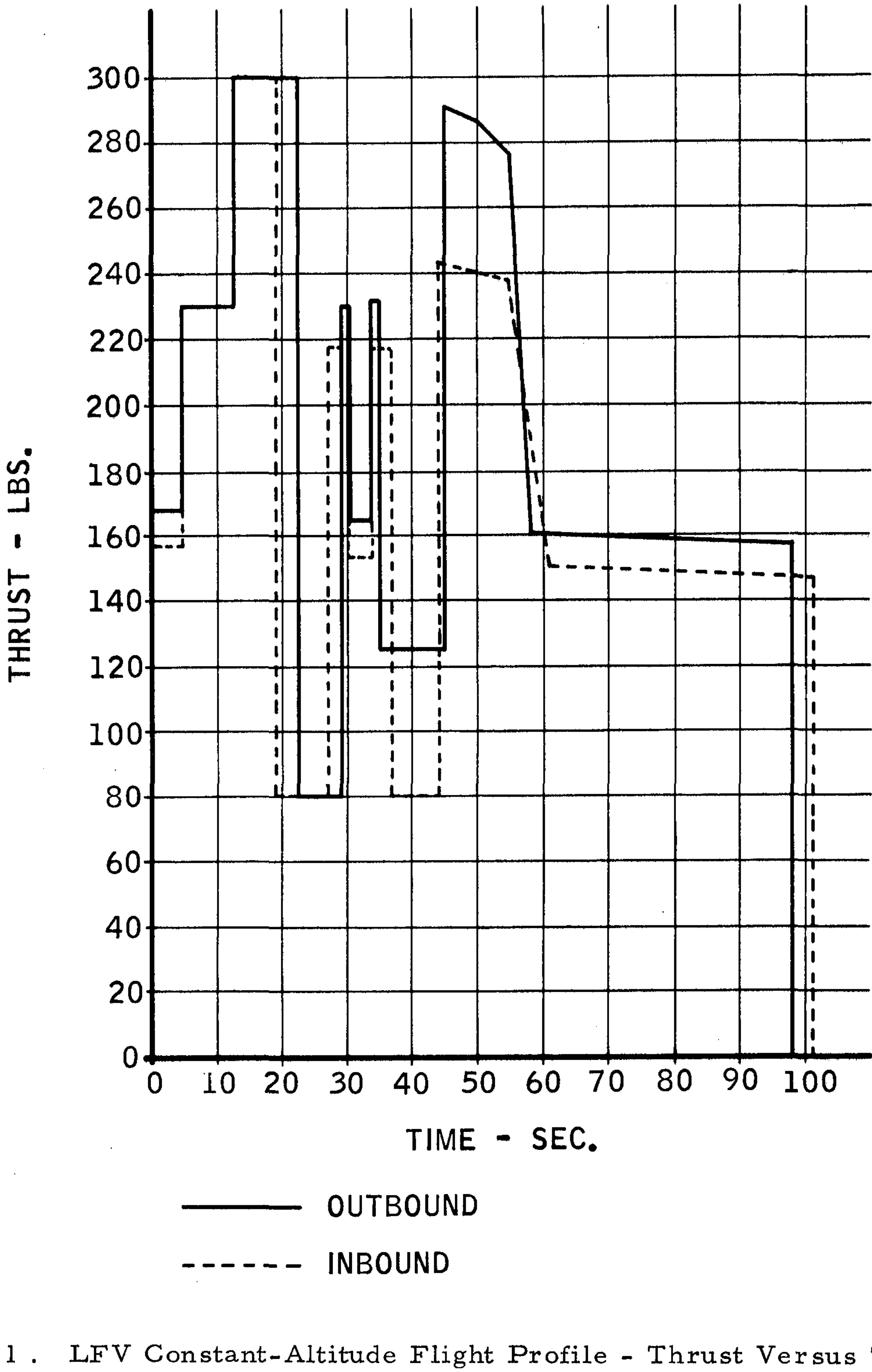



Figure 1 . LFV Constant-Altitude Flight Profile - Thrust Versus Time for 0. 5-NM-Range Sortie With 300 Pounds Maximum Thrust

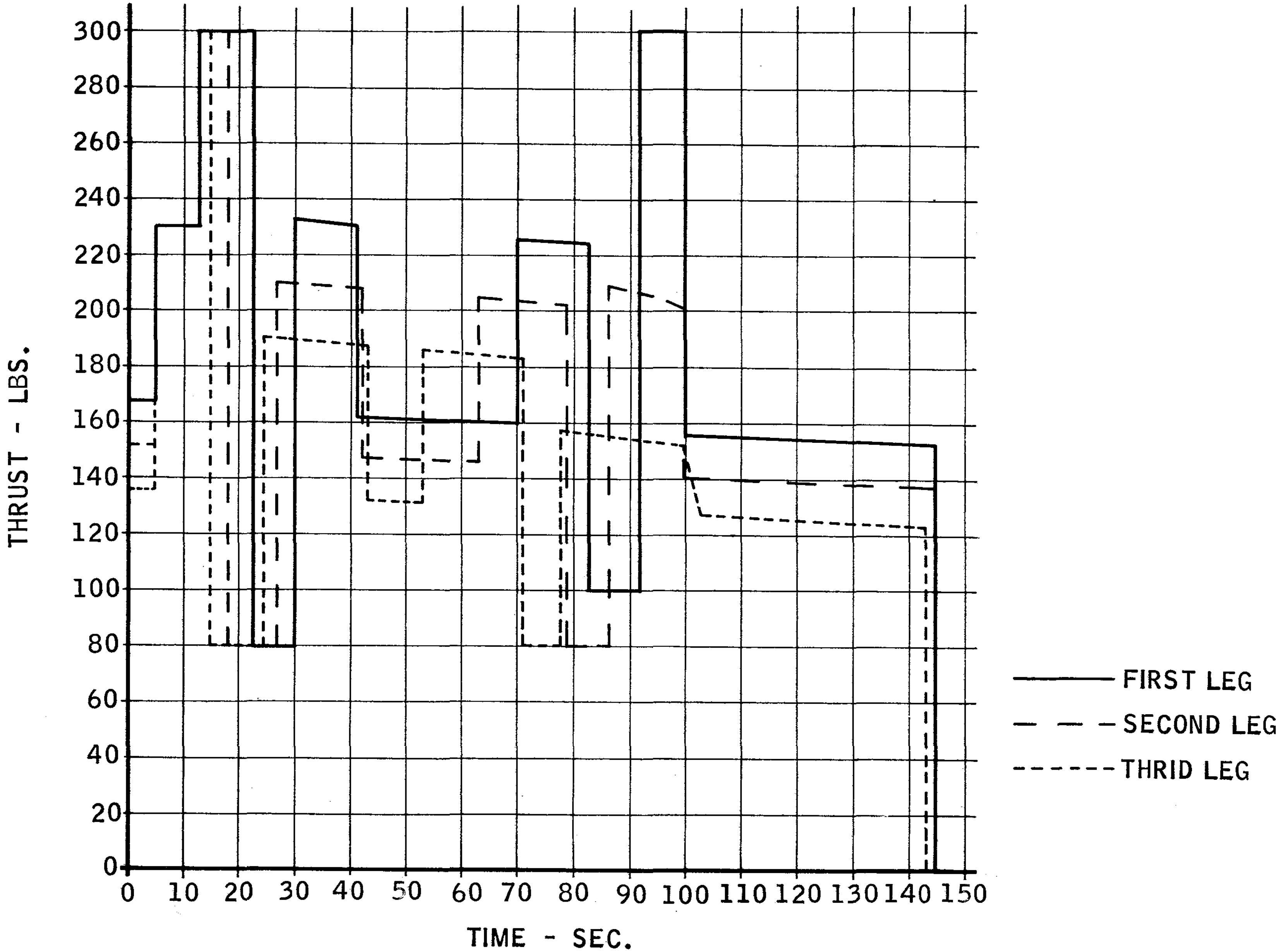



Figure 2. LFV Constant-Altitude Flight Profile - Thrust Versus Time for Triangular Sortie With 300 Pounds Maximum Thrust

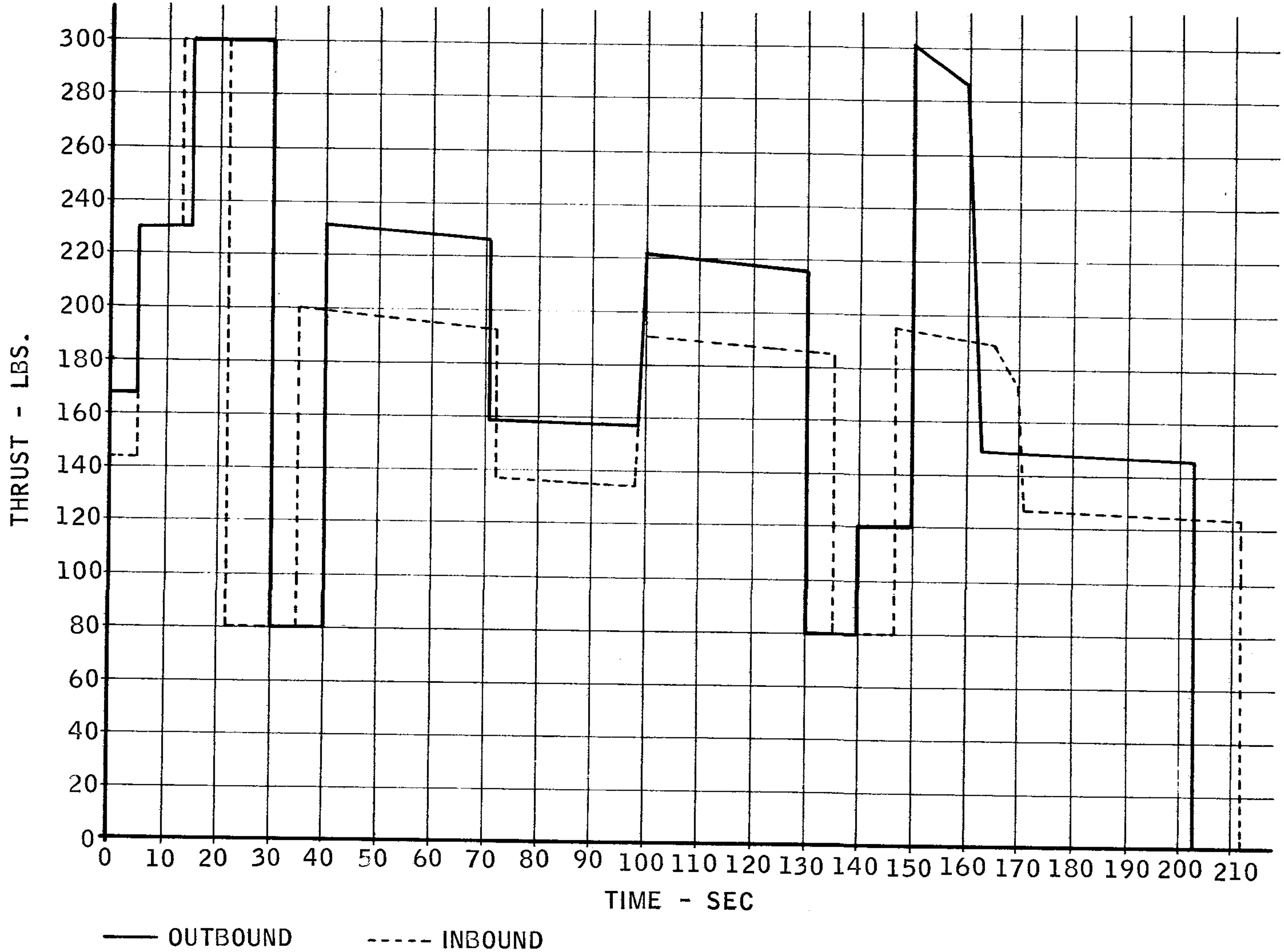



Figure 3. LFV Constant-Altitude Flight Profile - Thrust Versus Time for 5-NM-Range Sortie With 300 Pounds Maximum Thrust

3.1.2 Flight Elements. The lunar flying system flight elements consist of end items which will form the complete system necessary to provide a means of lunar surface exploration away from the LM. These items are:

The lunar flying vehicle
Lunar support equipment

The lunar flying vehicle components are:

Propulsion
Landing gear
Stability augmentation
Electrical power and distribution
Instrumentation/displays and control

The lunar support equipment components are:

Servicing
Takeoff mats
Spares and replacement
Checkout
Tools

3.1.2.1 System Engineering Documentation. The system specification tree is shown in Figure 4.

3.1.2.2 CEI List.

Lunar flying vehicle
Lunar support equipment
Development test articles

3.1.3 Operability.

3.1.3.1 Reliability. The mission success reliability for the lunar flying system shall apply to the design reference flight profile and is interpreted as the probability of successfully returning to the LM site without knowingly exceeding the crew safety limits. The crew safety reliability shall be the probability that there will be no crew loss due to LFV equipment failure over the design reference flight profile and shall include all detection and safe abort sequences. Mission success and crew safety objectives are .99 and .9995 respectively.

3.1.3.2 Dangerous Materials and Components. Requirements for micrometeoroid and radiation environments are found in paragraph 3.1.3.8.2. These requirements provide a design baseline for the lunar flying vehicle.

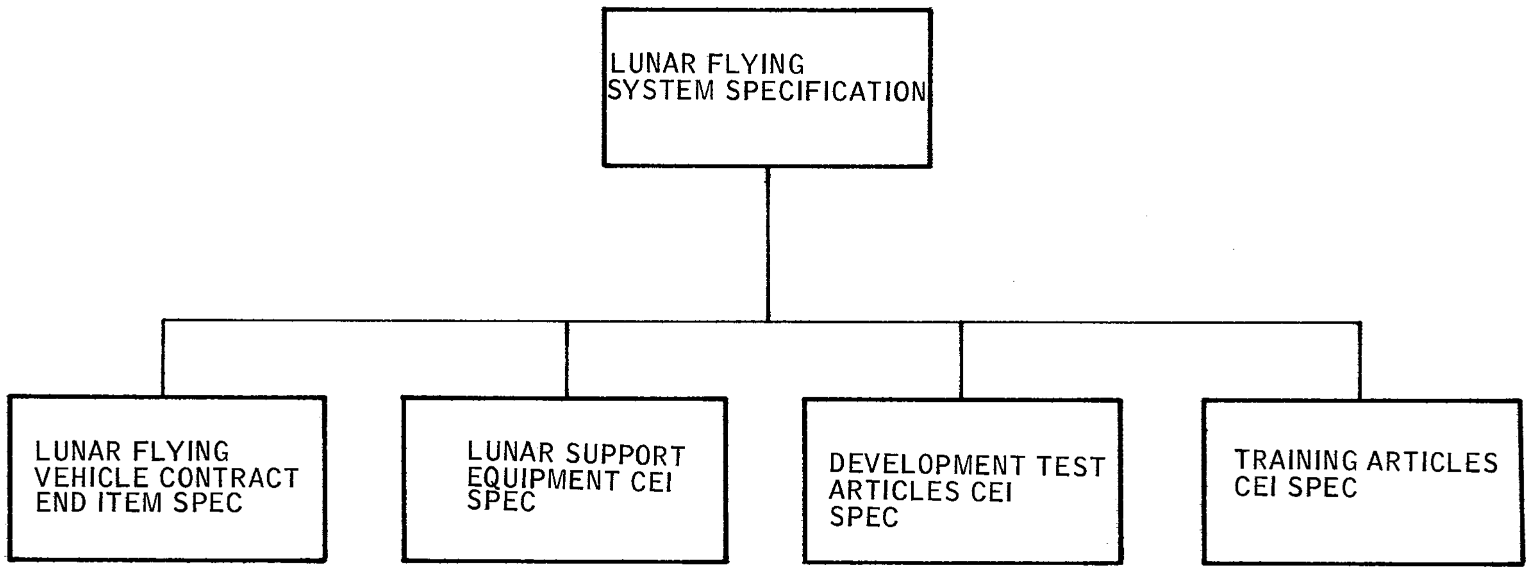



Figure 4. Specification Tree for Lunar Flying System

The LFV micrometeoroid protection shall be designed to give a probability of 0.992 of not requiring abort during the design reference flight profile.

3.1.3.3 Maintainability. There shall be no maintenance requirements on the system during preparation for launch or on the lunar surface.

3.1.3.4 Useful Life. The lunar flying system shall have a useful life to the design reference mission and flight profile. Where weight and reliability factors are not compromised, the system shall be designed for a maximum of 30 sorties.

3.1.3.5 Transportability. Equipment and modules shall be designed to be transported by common carrier utilizing a minimum of protection.

3.1.3.6 Human Performance. LFV system performance and operations shall be capable of being performed by one crew member. The design of the system shall take full cognizance of requirements for crew interface with respect to ingress, egress, visibility, and manipulative limitations. The pilot shall participate in navigation, control, monitoring, computing, and observation as required to utilize the system. The status of subsystems shall be displayed for monitoring failure detection and operational mode selection.

3.1.3.7 Safety. The LFV system shall be designed to exclude pyrotechnics. Astronaut safety shall be a prime requirement of the vehicle design. The LFV system shall utilize criteria that no operations, such as propellant servicing, removal from the LM, takeoff and landing, shall compromise astronaut safety or LM ascent stage and lunar launch operations integrity.

3.1.3.7.1 Personnel Safety. The design of the LFV shall minimize the hazards of fire, explosion, toxicity, and radiation to personnel. The hazards to be avoided include the leakage or accumulation of combustible fluids, spark or ignition sources (including static electricity discharge), radiation, and toxicity due to inhalation.

3.1.3.7.2 Equipment Safety. Appropriate safety provisions shall be included in the design of the LFV and shall consider the following typical safety requirements when applicable:

a. Connectors that could be cross-connected due to their location shall be sized, clocked, or pin-configured in such a manner that no external cables may be physically or electrically mated with wrong connectors.

b. When applicable, provisions shall include current-limiting devices to protect wiring and components.

c. Inlet and outlet ports shall be designed to preclude cross-connection due to their location. All ports shall be provided with appropriate markings to indicate flow direction, fluid type, and pressures utilized in the system.

3.1.3.8 Natural Environment. These requirements define the natural environment to which the LFV, the lunar support equipment, and associated ground maintenance (GSE) shall be designed.

3.1.3.8.1 Ground Environments. The following represents the natural environmental extremes which may be encountered by LFV equipment and GSE in a non-operating condition during transportation, ground handling, and storage. Exposed GSE shall be capable of operating during exposure to these environments. Other GSE and LFV equipment may be protected by suitable packaging for transportation and storage if these environments exceed the equipment design operation requirements. The equipment shall be capable of meeting the operating requirements of the applicable performance specification after exposure, while protected by its normal packaging, to these environments:

a. Temperature (air)

| | |
|---|---|
| Air transportation | -45 to +140 F for 8 hours |
| Ground transportation | -20 to +145 F for 2 weeks |
| Storage | +25 to +105 F for 3 years |

b. Pressure

| | |
|---|---|
| Air transportation | Minimum of 3.47 psia for 8 hours (35,000-ft altitude) |
| Ground transportation and storage | Minimum of 11.78 psia for 3 years (6000-ft altitude) |

c. Humidity — 0 to 100 percent relative humidity, including conditions wherein condensation takes place in the form of water or frost for at least 30 days

| | |
|---|---|
| d. Sunshine | Solar radiation of 360 Btu per square foot per hour for 6 hours per day for 2 weeks |
| e. Rain | Up to 0.6 inch per hour for 12 hours, 2.5 inches per hour for 1 hour |
| f. Sand and dust | As encountered in desert and ocean beach areas, equivalent to 140-mesh silica flour with particle velocity up to 500 feet per minute and a particle density of 0.25 gram per cubic foot. |
| g. Fungus | As experienced in Florida climate, materials will not be used which will support or be damaged by fungi |
| h. Salt spray | Salt atmosphere as encountered in coastal areas, the effect of which is simulated by exposure to a 5 percent salt solution by weight for 48 hours |
| i. Ozone | Three years of exposure, including 72 hours at 0.5 ppm, three months at 0.25 ppm, and the remainder at 0.05 ppm concentration |

3.1.3.8.2 Stowed Flight Environments. These requirements represent the natural environmental design criteria for the LFV flight equipment in a stowed condition as experienced during the various flight mission phases. The exposure time for each mission phase environment shall be as presented below, unless otherwise defined in this section:

| Mission Phase | Duration (hours) |
|---|---|
| Ascent | 0.20 |
| Earth parking orbit | 4.50 |
| Translunar injection | 0.09 |
| Translunar coast | 110.00 |
| Lunar orbit insertion, transfer | 17.3 |
| Activation, checkout, descent, touchdown | 5.6 |
| Lunar surface before removal | 18.3 |

The equipment shall be capable of meeting the operating requirements of the applicable performance specification after exposure to these environments.

Ascent Phase

| | |
|---|---|
| a. Reference atmosphere | The reference earth atmosphere at Cape Kennedy, Florida, shall be in accordance with NASA TM X-53139. Pressure decay time is two minutes. |

Earth Parking Orbit, Translunar Injection, Translunar Coast, Lunar Orbit Insertion, Activation to Touchdown

| | |
|---|---|
| a. Pressure | $10^{-8}$ torr |
| b. Electromagnetic radiation | The sources of electromagnetic radiation presented below impinge on the exterior of the CSM in logical combination for a total time up to 336 hours |
| Solar flux (all wavelengths) | 442 Btu/ft$^2$-hour |
| Earth emission (excluding reflection) | 73 Btu/ft$^2$-hour |
| Lunar subsolar point emission | 419 Btu/ft$^2$-hour |
| Lunar antisolar point emission | 2.2 Btu/ft$^2$-hour |
| Lunar average albedo (visual range) | 0.073 Btu/ft$^2$-hour |
| Lunar average reflectance for total solar spectrum | 0.047 ± .006 |
| Earth average albedo (visual range) | 0.40 |

| | |
|---|---|
| Earth average albedo (total solar spectrum) | 0.34 to 0.50 |

(Thermal energy distribution to be interpreted according to cosine law.)

| | |
|---|---|
| Space sink temperature | Zero degrees rankine |
| Lunar surface temperature | Variable from +250 to -300 F and to be established from thermal analysis accounting for shadowing and lunar daytime |

c. Meteoroid (environment) — The flux-mass sporadic meteoroid model for CSM exterior exposure in near-earth, cislunar, and near lunar space shall be as presented in NASA MSC Design Standard DS-21 Code 1.1 "Meteoroid Environment-Near Earth Cislunar." Lunar Surface Model is to be added when issued by the NASA

d. Nuclear radiation - The nuclear radiation environments for near-earth, cislunar, and near-lunar space shall be as presented below. Spacecraft design shall be based on exposure during a 14 day LOR mission. Crew safety assessment shall be based on exposure during an 8.3 day LOR mission.

(1) Trapped Radiation - Radiation levels in the Van Allen and artificial belts will use proton and electron fluxes obtained with the Goddard Orbital Flux Code.

(2) Galatic Cosmic Rays - Galactic cosmic ray doses range from 0.1 rad per week for solar activity maximum to 0.3 rad per week for solar activity minimum.

(3) Solar Particle Events - The solar particle environments shall be as specified in NR Specification SID 64-1344, CSM Technical Specification (Block II).

(4) Lunar Surface Stay Conditions - Sun angle: 10 deg to 47 deg (3 days); lunar latitude ±42 degrees.

3.1.3.8.3 Induced Environment. These requirements define the induced environmental criteria to which the LFV equipment and associated GSE shall be designed.

3.1.3.8.4 Ground Environments. The following represent the induced environmental extremes which may be encountered by LFV equipment and GSE in a non-operating condition during transportation, ground handling, and storage. Handling GSE shall be capable of operating during exposure to the environments. Other GSE and LFV equipment may be protected by suitable packaging for transportation and storage if these environments exceed the equipment design operation requirements. The equipment shall be capable of meeting the operating requirements of the applicable performance specification after exposure, while protected by its normal packaging, to these environments.

a. Shock

(1) Packaging - The design shock levels applicable to protective packaging, or directly to equipment when packaging is not used, shall be those resulting from free-fall drops as presented in the table below. The protective packaging shall attenuate shock to such an extent that packaged LFV equipment and GSE will not be exposed to shock levels exceeding the equipment design operating requirements.

| Weight* (lb.) | Dimensions** not Exceeding (in.) | Drop Height | | |
|---|---|---|---|---|
| | | Free Fall (in.) | Edgewise (in.) | Cornerwise (in.) |
| Less than 50 | 36 | 30 | | |
| 50 to 100 | 48 | 21 | | |
| 100 to 150 | 60 | 18 | | |
| 150 to 200 | 60 | 16 | | |
| 200 to 600 | 72 | | 36 | 36 |
| Over 600 | Over 72 | | 24 | 24 |

*Weight of equipment and package or containers (if used)
**Dimension along any edge or diameter

(2) Equipment - The design shock levels applicable directly to LFV equipment and GSE, which utilized protective packaging, for which no other design operating requirements are established, shall be as presented in the following table:

| Weight (lb)* | Shock Level (g)** | Time (ms) |
|---|---|---|
| Less than 250 | 30 | 11 ±1 (half-sine waveform) |
| 250 to 500 | 24 | 11 ±1 (half-sine waveform) |
| 500 to 1000 | 21 | 11 ±1 (half-sine waveform) |
| Over 1000 | 18 | 11 ±1 (half-sine waveform) |

*Weight of equipment and package or containers (if any)
**As experienced in any direction

b. Vibration - Sinusoidal as experienced in any direction

| Weight (lb)* | 5 to 26.5 cps | 26.5 to 52 cps (inch DA) | 52 to 500 cps |
|---|---|---|---|
| Less than 50 | ±1.56 g | 0.043 | ±6.0 g |
| 50 to 300 | ±1.30 g | 0.036 | ±5.0 g |
| 300 to 1000 | ±1.30 g | 0.036 | |
| Over 1000 | ±1.04 g | 0.029 | |

*Weight of equipment and package or containers, if any

3.1.3.8.5 Stowed Flight Induced Environment. The following environmental and load conditions are extracted from Grumman Report ARP325-7B and shall be considered applicable for integrating the LFV into the ELM descent stage.

3.1.3.8.6 Saturn V Launch and Boost

a. Acceleration

LM Coordinates

| Condition | X | | Y | | Z | |
|---|---|---|---|---|---|---|
| | g | Rad/sec$^2$ | g | Rad/sec$^2$ | g | Rad/sec$^2$ |
| Liftoff condition | +1.60 | - | ±.65 | - | ±.65 | - |
| Max-q condition (S-IC) | +2.07 | - | ±.30 | - | ±.30 | - |
| Boost condition (S-IC) | +4.90 | - | ±.10 | - | ±.10 | - |
| Cutoff condition (S-IC) | -1.70 | - | ±.10 | - | ±.10 | - |
| Engine hardover (S-II) | +2.15 | - | ±.40 | - | - | - |
| Engine hardover (S-II) | +2.15 | - | - | - | ±.40 | - |
| Engine hardover (S-IVB) | +1.87 | 0 | ±.23 | ±.70 | ±.23 | ±.70 |
| Earth orbit | 0 | | 0 | 0 | 0 | 0 |

b. Vibration

The mission vibration environment is represented by the following random and sinusoidal envelopes considered separately (these represent input to equipment supports from exterior primary structure; appropriate account must be taken for transmissibility of secondary structure):

c. Random

| | |
|---|---|
| 10 to 23 cps | 12 db/oct rise to |
| 23 to 80 cps | .0148 $g^2$/cps |
| 80 to 105 cps | 12 db/oct rise |
| 105 to 950 cps | .0444 $g^2$/cps |
| 950 to 1250 cps | 12 db/oct decrease to |
| 1250 to 2000 cps | .0148 $g^2$/cps |

d. Sinusoidal

| | |
|---|---|
| 5 to 18.5 cps | 0.154 in DA |
| 18.5 to 100 cps | 2.69 g peak |

For design purposes, the above random spectrum will adequately represent the environment when applied for five minutes along each of the three mutually perpendicular axes (X, Y, and Z) in addition to the corresponding sinusoidal spectrum acting for five seconds at the natural frequency of the equipment being designed. During the launch and boost phase of flight, the ELM is exposed to random vibration of varied levels and spectra for 17 minutes. During all but approximately 2.5 minutes of this period, the intensity of the random vibration is of such low level that it is considered to be of negligible design significance. In addition, the launch and boost environment is considered to include peak vibration levels which are represented by the above sinusoidal vibration envelopes. The number of sinusoidal peaks for design can be considered to be one percent of the natural frequency of the equipment being designed times the number of seconds of exposure. Vibration levels may be lower at specific equipment locations due to the reaction of equipment on primary structure. Therefore, a rationally demonstrated reduction in these levels may be used for ELM equipment design and test.

e. Acoustics

Sound pressure levels are expressed in db external to the ELM with the Saturn at max q level. The db reference is 0.0002 dynes/cm$^2$.

| Octave Band (cps) | Sound Pressure (db) |
|---|---|
| 9 to 18.8 | 127 |
| 18.8 to 37.5 | 133 |
| 37.5 to 75 | 136 |
| 75 to 150 | 134 |
| 150 to 300 | 129 |
| 300 to 600 | 125 |
| 600 to 1200 | 120 |
| 1200 to 2400 | 116 |
| 2400 to 4800 | 112 |
| 4800 to 9600 | 107 |
| overall | 141 |

3.1.3.8.7 Lunar Descent. These requirements cover separation, descent, hover, and touchdown:

a. Acceleration

| | Coordinates | | | | | |
|---|---|---|---|---|---|---|
| | X | | Y | | Z | |
| Condition | g | Rad/sec$^2$ | g | Rad/sec$^2$ | g | Rad/sec$^2$ |
| Descent engine operating | +.82 | ±.19 | ±.08 | ±.65 | | ±.65 |
| Transfer orbit | 0 | 0 | 0 | 0 | 0 | 0 |
| Landing condition I | .674 | ±.125 | ±1.356 | 0 | 0 | ±10.913 |
| Landing condition II | .674 | 0 | 0 | ±13.121 | ±1.356 | 0 |
| Landing condition III | .703 | ±11.468 | ±.033 | 6.714 | -.345 | ±.304 |
| Landing condition IV | 2.375 | 0 | 0 | ±22.044 | ±.337 | 0 |
| Landing condition V | 2.375 | ±.210 | ±.337 | 0 | 0 | ±18.334 |

Landing accelerations are steady state at center of gravity of the ELM.

b. Shock

Landing shock will have 20 ms rise time, 200 ms dwell time, and 40 ms decay.

| | Coordinates | | | | | |
|---|---|---|---|---|---|---|
| | X | | Y | | Z | |
| Condition | g | Rad/Sec$^2$ | g | Rad/Sec$^2$ | g | Rad/Sec$^2$ |
| Landing case 1 | 8.0 | | | ± 14.0 | | |
| Landing case 2 | | | ± 8.0 | | | ± 14.0 |
| Landing case 3 | | | | ± 14.0 | ± 8.0 | |
| Landing case 4 | 8.0 | | | | | ± 14.0 |

c. Vibration.

The mission vibration environment is represented in the following random and sinusoidal envelopes considered separately (these represent input from primary structure to descent stage equipment support; appropriate account must be taken for transmissibility of secondary structure):

Random

| | |
|---|---|
| 10 to 30 cps | 6 db/oct rise to |
| 30 to 60 cps | 0.085 $g^2$/cps |
| 60 to 175 cps | 6 db/oct decrease to |
| 175 to 2000 cps | 0.010 $g^2$/cps |

Sinusoidal

| | |
|---|---|
| 5 to 23 cps | 0.1 in DA |
| 23 to 1000 | 2.77 g peak |

For design purposes, the above random spectrum will adequately represent the environment when applied for 12-1/2 minutes along each of the three perpendicular axes (x, y, and z) in addition to the corresponding sinusoidal.

d. Temperatures

Temperature limits of the LM descent stage and external skins are tabulated below:

| | Temperature (F) | |
|---|---|---|
| Mission Phase | Structure | External Surface |
| Launch & boost | 30 to 100 | -65 to 270 |
| Translunar | 20 to 100 | -300 to 270 |
| Descent | 20 to 100 | -300 to 270 |
| Lunar surface | 20 to 160 | -300 to 270 |

RCS plume impingement is to be considered separately per LFV/LM interface requirements of Grumman Corporation Report ARP 325-7B.

3.2 System Design and Construction Standards. The LFV system shall utilize MIL-Handbook 5A February 1966, Metallic Materials and Elements for Aerospace Vehicular Structures.

3.2.1 General Design and Construction Requirements

3.2.1.1 Factors of Safety. The factors of safety specified below are minimum and shall be used in addition to vibration amplification factors, casting factors, bearing factors, etc.

3.2.1.1.1 Proof Pressure Factor. The proof pressure factor shall be the maximum limit pressure times 1.5. The yield pressure shall be 1.66 times maximum limit pressure.

3.2.1.1.2 Burst Pressure Factor. The burst pressure factor shall be the maximum limit pressure times 2.0.

3.2.1.1.3 Yield Factor of Safety. The yield factor of safety shall be 1.1 times the limit mission loads.

3.2.1.1.4 Ultimate Factor of Safety. The ultimate factor of safety shall be 1.5 times the limit mission loads.

3.2.1.2 Selection of Specifications and Standards. Specifications and standards for use in the design and construction of the LFV system shall be selected in the order of precedence in accordance with MIL-STD-143. Only those documents listed in the Department of Defense Index of Specifications and Standards shall be interpreted as Group I in accordance with MIL-STD-143. Government Agency Specifications and Standards other than those listed in the above noted document (e.g., NASA, FAA) shall be interpreted as Group III in accordance with MIL-STD-143. All standards or specifications, other than those established and approved for use by the Government, must be approved by the Procuring Agency prior to incorporation in this specification or the CEI specifications.

3.2.1.3 Materials, Parts, and Processes. All materials, parts, and processes selected for use in design and construction of the LFV system shall be compatible with the performance and environmental criteria for the end item as specified in the CEI specification.

3.2.1.4 Standard and Commercial Parts. Standard parts and components shall be used wherever they are suitable for the purpose and shall be

identified by part number where practical. Commercial parts such as screws, bolts, nuts, and cotter pins may be used provided they are suitable for the intended purpose and are replaceable by a standard part without alteration. Commercial parts and components may be used provided there is no suitable standard part or component.

3.2.1.5 Moisture and Fungus Resistance. Non-nutrient materials shall be used in the LFV system to resist damage from moisture and fungus. Protective coatings shall not be acceptable as moisture and fungus preventives on parts which lose the coating during the normal course of operation, inspection, maintenance, and periodic testing. Resistance to fungi shall be in accordance with Requirement 4, Fungus Inert Materials, of MIL-STD-454.

3.2.1.6 Corrosion of Metal Parts. Finishes shall be supplied to metal parts which are subject to corrosion to insure adequate protection in the specific environment.

3.2.1.7 Interchangeability and Replaceability. LFV system assemblies, components, and parts shall be selected and designed wherever possible to be interchangeable and replaceable in accordance with the definitions given in MIL-STD-721.

3.2.1.8 Workmanship. The LFV system shall be fabricated and finished to the standards of workmanship specified to control fit and appearance, and in accordance with manufacturing practices that will produce equipment free of defects.

3.2.1.9 Electromagnetic Interference (EMI). Each assembly shall be electromagnetically compatible with other assemblies in the system, other equipment in or near the launch vehicle, associated test and checkout equipment, and to the electromagnetic radiation of the operational environment in accordance with MIL-STD-461 and 462. The subsystem shall not be a source of interference that could adversely affect the operation of other equipments or compromise its own operational capabilities. The system shall not be adversely affected by fields or voltages reaching it from external sources, such as improperly suppressed vehicle checkout and test equipment, or nearby frequency sources in the operational environment.

3.2.1.10 Identification and Marking

a. Wires, with the exception of junction box, patching, and jumper wires, shall be in accordance with MIL-STD-681.

c. Fluid lines shall be identified in accordance with MIL-STD-1247. Fluid lines shall be marked to indicate the fluid medium. The design operating pressure, and the direction of fluid flow.

c. Instruction plates shall be securely fastened to enclosures and shall be placed in a position where they can be easily read.

d. Precautionary markings shall be provided as necessary to warn personnel of hazardous conditions and precautions to be observed to insure the safety of personnel and equipment.

3.2.1.11 Storage. The LFV hardware shall be designed for a storage life of three years, except that in those cases where age-sensitive materials cannot be avoided, replacement of such materials shall be permitted on a scheduled basis during the storage period.

3.3 Performance Allocations

3.3.1 Lunar Flying Vehicle System

3.3.1.1 Allocated Performance and Design Requirements. The LFV shall be capable of supporting payloads from 0 to 370 pounds with densities as shown in Figure 5. The dry weight (LM load) of the vehicle system shall not be more than 400 pounds. The vehicle shall be capable of an operating radius with specified payloads as shown below.

| Operating Radius (nm) | Outbound & Inbound Payload (lb) |
|---|---|
| 4.6 | 0 |
| 3.5 | 100 |
| 1.7 | 370 |

The vehicle shall be capable of a landing gear life of 30 landings and takeoffs; a storage life (dry) of 90 days, and a standby life (loaded) of three days.

3.3.1.2 Functional Interfaces. The LFV shall be carried in the LM corner compartment with environments and loads as shown on Interface Document (GAEC ARP 325-7B) modified as follows:

a. A penetration of the aft bulkhead to the plane at LM "X-coordinate" 116.3 (aft heatshield).

b. Penetration into the LM RCS plume impingement area to the SLA interface.

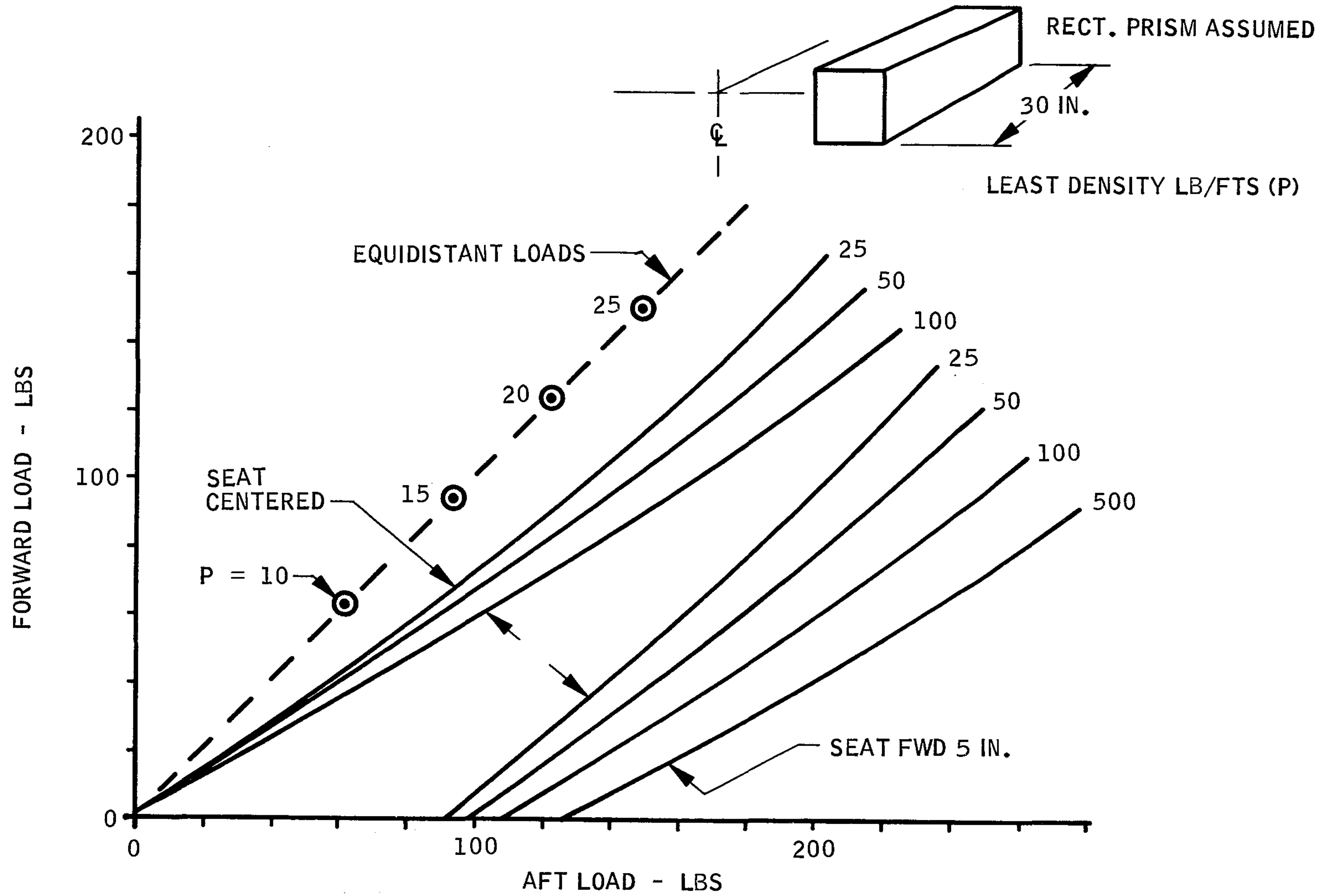



Figure 5. Payload Density Envelope

c. The aft bulkhead corner angle brace shall be removable for LFV stowing and be made removable on the lunar surface with a simple accessible device.

d. LM structural modification weight shall not exceed 15 pounds.

3.3.2 The Lunar Support Equipment System.

3.3.2.1 Allocated Performance and Design Requirements. The LSE system weight shall not exceed 90 pounds including LM stowing equipment. The LSE system shall be performing respective functions under the following schedule:

| Function | Time (hr) |
|---|---|
| LM Removal | 0.2 |
| Deployment time | 0.4 |
| Propellant servicing & checkout | 0.8 |
| Storage life (dry) | 30 days |
| Takeoff mats | 10 landings |

3.3.2.2 Functional Interfaces. The interfaces between the LSE and the LM are:

a. The LSE shall be stowed in accordance with the GAEC interface document (Grumman Corporation Report ARP 325-7B).

b. Servicing propellant (oxygen and fuel) hoses shall be permanently connected to a low point of the LM propellant system.

c. A manual operated valve, accessible to the disembarked astronaut, shall isolate the LFV hoses from the LM piping.

d. The LM propellant tank vent controls shall be provided to vent the system to an adjustable pressure range of 15 to 50 psia after LM landing.

3.3.3 Portable Life Support System (PLSS)

3.3.3.1 Allocated Performance and Design Requirements. The LFV and LSE shall be operable and dimensionally compatible with suited astronauts in pressurized lunar surface condition.

3.3.3.2 Functional Interfaces. Electrical connections shall be provided between the LFV and the PLSS for actuation of two different audible alarm signals.

# 4. QUALITY ASSURANCE PROVISIONS

4.1 General Quality Assurance Program. NR/SD shall establish a quality assurance program in accordance with the provisions of Contract NAS 9-150. Inspections and tests to determine conformance of the system of contract and specification requirements shall be conducted prior to submission of the article to the NASA for acceptance. Documentation requirements shall be as noted in Exhibit I to the Apollo Contract, NAS 9-150.

4.2 Reliability Program. NR/SD shall implement a reliability program in accordance with the provisions of the contract.

4.3 Test. Performed at component, subsystem, and integrated system level to demonstrate specified design margins. NR/SD shall establish a qualification test program and an acceptance test program to determine that the LFV system satisfies the requirements of Section 3 of this specification. The definitions and ground rules for establishing this program are as follows:

4.3.1 Definitions.

a. Qualification tests - Functional tests performed on production hardware at and above mission levels of all critical environments to assure that the hardware will meet the design requirements and will perform its function for its use cycle.

b. Criticality - Criticality describes the impact of failure of equipment (part, component, subsystem) on crew safety or mission success. Criticality is non-numerical and is classified as follows:

   Criticality I - Those items whose failure may result in loss of crew.

   Criticality II - Those items whose failure may result in loss of mission.

   Criticality III - Those items whose failure does not affect mission success or crew safety.

c. Production hardware - Hardware that is manufactured with the same tooling, processes, quality control procedures, and to the same design as that which will be used in manned flight.

d. Failure - The inability of a system, subsystem, component, or part to perform its required function within specified limits under specified conditions for a specified duration.

e. Operational cycle - The period of time extending from the beginning of acceptance tests to the end of a mission that a system, subsystem, component or part is expected to operate under sequential application of events, induced or natural.

f. Acceptance tests - Those inspections, environmental exposures, and functional tests performed on production hardware to provide assurance that the hardware meets configuration and performance specifications.

4.3.2 Qualification Test Ground Rules.

a. The qualification program is limited to tests conducted on individual parts, components, subassemblies, assemblies, and subsystems. The qualification program shall consist of a series of tests at any or all assembly levels listed above. Generally, these shall occur only at the highest practical level of assembly. If tests are required at several levels, those at lower levels shall be initiated prior to those at higher levels of assembly.

b. Production hardware shall be used throughout.

c. Acceptance tests shall precede all qualification tests.

d. No refurbished equipment shall be used without specific NASA approval.

e. Functional operation is required. During all qualification tests all interfaces shall be present or simulated.

f. Adjustments will be permitted during an operational cycle only if they are part of a normal procedure.

g. Limited life items and single-shot devices may be replaced at the completion of satisfactory operation through their lifetime requirements.

h. Any failure shall be cause for positive correction action. The degree of retest in event of failure shall be agreed upon between NASA and the contractor after evaluation of the failure. In event of failure, the contractor shall immediately advise NASA.

i. Requalification shall be performed when:

   (1) Design or manufacturing processes are changed to the extent that the original tests are invalidated.

   (2) Inspection, test, or other data indicate that a more severe environment or operational condition exists than that to which the equipment was originally qualified.

   (3) Manufacturing source is changed.

j. Qualification by similarity may be accepted provided:

   (1) The item was qualified to the LFV environmental levels, and

   (2) The item was fabricated by the same manufacturer with the same processes and quality control.

   (3) The item was designed to equivalent specifications required of the LFV designs.

k. Qualification testing shall include both natural and induced environments which simulate, as closely as required, the anticipated environments during the operational cycles in level, range, and sequence. Combined environments shall be used when necessary and practical.

l. Where redundancy in design exists, the qualification test program will assure that each redundant component will be included in the test program.

m. Qualification test specifications shall be written for each item, and the qualification test program will fully encompass the design specification requirements.

o. Subsequent to the completion of the qualification test program, further tests shall be conducted at conditions more severe than design limit. The purpose of these tests shall be to determine failure modes actual design margins.

### 4.3.3 Acceptance Test Ground Rules.

a. Applicability - Acceptance testing shall include all inspections and tests used as a basis for acceptance by the contractor. Acceptance testing may include tests on parts, equipments, or

subsystems, excluding GSE and spares. These requirements shall apply to the acceptance of hardware by the prime contractors from the subcontractors and to the acceptance of in-house produced hardware by the prime contractors.

b. Program Design

1. Acceptance tests shall be performed on the item prior to delivery or upon completion of in-house manufacture.

2. Acceptance tests of equipment shall be technically integrated with the manufacturing tests and the vehicle checkout so that the total program is designed to provide assurance that each contract end item is capable of fulfilling its required end use.

3. Acceptance testing shall include functional tests, environmental exposures as required, and inspection techniques designed to:

   (a) Locate manufacturing defects.

   (b) Locate handling damage.

   (c) Provide assurance that no malfunction exists prior to shipping.

   (d) Provide assurance that items conform to their performance specification and other approved performance criteria.

4. Acceptance testing may include calibration and/or alignment.

5. The degree, duration, and number of tests and checks shall be sufficient to provide assurance that each item possesses the required quality and performance without degradation to the item.

c. Procedure

1. Selection of the acceptance test and checkout procedures shall be based upon the performance requirements of the item.

2. Where possible, without degradation or destruction of the tested item, all normal, alternate, redundant, and emergency operational modes shall be demonstrated.

3. The functional tests shall simulate end use to the highest degree practicable without degradation of the operational or life characteristics of the item. Sampling plans may be employed when the tests are destructive or when the classification of characteristics, the records, or non-critical application of the item indicates that less testing is required.

4. If calibration of the equipment is necessary, then calibration and alignment shall be performed on the equipment in order to detect and adjust any variation in its accuracy prior to test. No adjustments shall be made during the conduct of the test unless it represents a normal operating procedure.

5. Final inspection techniques shall include visual examination, measurements, non-destructive tests, and special procedures such as X-ray, infrared, ultrasonics, and optical alignment where required.

d. Environments

1. Each item shall be subjected to only those environmental tests necessary to reveal defects without overstressing or degradation.

2. Selection of the environments and stress levels shall be based upon design specifications and/or end use requirements and, if available, the results of development and qualification tests. The performance trends versus stress as observed during development and qualification tests may be used to modify these environments and/or stress levels.

3. Environmental exposure shall be limited to the acceptance testing following manufacturing.

e. Implementation - In accordance with the provisions of NPC 200-2 and/or the contract, suppliers of LFV equipment shall:

1. Prior the the start of testing, submit a test plan for review adequately defining the test philosophy of the referenced component or subsystem.

2. Submit a detailed test procedure for the unit specifying environments, the test equipment, the sequence of tests, the test parameters, and the methods of testing.

3. Report to NASA any unusual phenomenon, difficulty, or questionable condition occurring during acceptance testing.

# LUNAR FLYING VEHICLE
# CONTRACT END ITEM SPECIFICATION

## 1. SCOPE.

1.1 Scope. This specification establishes the design and performance requirements for the lunar flying vehicle (hereafter referred to as the LFV).

1.2 Objective. The objective of this specification is to provide baseline design requirements for the LFV as necessary to meet the requirements established in the Lunar Flying System Specification.

## 2. APPLICABLE DOCUMENTS.

2.1 Applicability. The following documents of the exact issue shown form a part of this specification to the extent specified herein. In the event of a conflict between the documents referenced herein and the contents of the specification, the contents of this specification take precedence.

SPECIFICATIONS

Military

| | |
|---|---|
| MIL-S-7742B<br>2 February 1968 | Screw Threads, Standard, Optimum Selected Series, General Specification for |
| MIL-A-8625C<br>15 January 1968 | Anodic Coating, for Aluminum and Aluminum Alloy |
| MIL-S-8879A<br>8 December 1965 | Controlled Radius Root With Increased Minor Diameter, General Specification for |
| MIL-I-26600(2)<br>9 May 1960 | Interference Control Requirements, Aeronautical Equipment (As Amended by MSC-ASPO-EMI-10A dated 17 October 1963) |

| | |
|---|---|
| MIL-P-27407(1)<br>8 January 1965 | Propellant Pressurizing Agent, Helium |

Marshall Space Flight Center (MSFC)

| | |
|---|---|
| MSFC-SPEC-164(4)<br>17 July 1964 | Cleanliness of Components for Use in Oxygen, Fuel, and Pneumatic Systems, Specification for |
| NPC 200-4<br>August 1964 | Quality Requirements for Hand Soldering of Electrical Connections |
| 10M01071<br>6 March 1961 | Environmental Protection When Using Electrical Equipment Within the Area of Saturn Complexes When Hazardous Areas Exist |

North American Rockwell Corporation Space Division (NR SD)

| | |
|---|---|
| MA0116-029E<br>9 December 1968 | Age Control Standard for Age-Sensitive Rubber Items |

STANDARDS

Military

| | |
|---|---|
| MIL-STD-12B<br>18 May 1959 | Abbreviations for Use on Drawings and in Technical Type Publications |
| MIL-STD-100A<br>1 October 1967 | Engineering Drawing Practices |
| MIL-STD-1290<br>13 March 1967 | Marking for Shipment and Storage |
| MIL-STD-143A<br>14 May 1963 | Specifications and Standards, Order of Precedence for the Selection of |
| MIL-STD-171B<br>16 March 1965 | Finishing of Metals and Wood Surfaces |

| | |
|---|---|
| MIL-STD-794A<br>26 June 1967 | Parts and Equipment Procedure for Packaging and Packing of |
| MIL-STD-810B<br>15 June 1967 | Environmental Test Methods |

PUBLICATIONS

3. REQUIREMENTS

3.1 Subsystems. The LFV shall include the following subsystems:

a. LFV stability augmentation

b. LFV propulsion

c. LFV instrumentation, control, power

d. LFV landing gear

e. Structural

3.2 Selection of Specifications and Standards. Specifications and standards for use in the design and construction of the LFV shall be selected in the order of precedence in accordance with MIL-STD-143.

3.3 Materials, Parts, and Processes

3.3.1 Standard Parts. Standard parts and components shall be used wherever they are suitable for the purpose.

3.3.2 Moisture and Fungus Resistance. Materials which are nutrient to the fungi defined in MIL-STD-810, Method 508, shall not be used unless this is impractical. When fungus nutrient materials must be used they shall be hermetically sealed or treated to prevent fungus growth for a period of five years. Fungus treatment shall not adversely affect equipment performance or service life. Items so treated shall be protected from moisture that would be sufficient to leach out the protective agent.

3.3.3 Corrosion Resistance. Metallic materials shall be corrosion-resistant by nature or by means of a protective coating. Base metals intended for intermetallic contact that form couples not allowed by MIL-STD-171 shall be plated with those metals which will reduce the potential difference or shall be suitably insulated by a nonconducting finish. Electrical bonding methods shall include provisions for corrosion protection of mating surfaces.

3.3.4 Toxic Effect. Materials shall not be used that generate toxic products when exposed to the environmental conditions specified herein.

3.3.5 Flammable Material. Materials shall not be used that support combustion or are capable of producing flammable gases (which, in addition to other additives to the environment, may reach flammable concentration.

3.3.6 Material Compatibility. Materials and processes used in fabrication of the LFV shall be compatible with the environmental conditions specified herein.

3.3.7 Anodizing. Anodizing of aluminum alloy, if required, shall be in accordance with MIL-A-8625, Type II. Anodizing shall be limited to those surfaces which are not exposed to propellants.

3.3.8 Age Control. Where practical, elastomer materials shall not be used that require age control. Otherwise, elastomers shall be age-controlled in accordance with MA0116-029.

3.3.9 Cleanliness. The LFV level of cleanliness shall be in accordance with MSFC-SPEC-164, except particle size and quantity shall be to the following requirement:

| Particle Size | Quantity per 100 Milliliters of Rinse Fluid |
|---|---|
| a. Particles larger than 250 microns | None permissible |
| b. 200 to 250 microns | 1 particle |
| c. 160 to 200 microns | 5 particles |
| d. Less than 160 microns | Up to total filterable solids limit |

Total filterable solids shall not be greater than 2.0 milligrams (mg's) per liter of rinse fluid based on 100 ml's of rinse fluid per square foot of significant surface area. Nonvolatile residue shall not be greater than 1.0 mg per square foot of significant area based on 100 ml's of rinse fluid per square foot of significant surface area.

3.3.9.1 Contamination From Operation. The LFV shall not generate or otherwise contribute to contamination of the fluid media.

3.3.10 Soldering. All soldering of electrical connections shall conform to the requirements of NPC 200-4 as supplemented by ASPO S-6.

3.3.11 Threads and Fasteners. Screw threads shall be in accordance with MIL-S-7742 or MIL-S-8879 for fastener ultimate tensile strengths below 160, 000 pounds per square inch (psi). MIL-S-8879 shall be used for fastener ultimate tensile strengths 160, 000 psi and above. External threads per MIL-S-8879 for fastener tensile strengths 160, 000 and above shall be produced by a single thread-rolling process after final heat treatment. Removable, externally threaded bushing-type, corrosion-resistant, steel inserts shall be used in tapped holes in aluminum alloys and magnesium alloys where frequent removal of the threaded part will be encountered in normal service or maintenance. Coiled-wire-type inserts shall not be used.

3.3.12 Electrical Bonding. Electrical bonding shall be in accordance with MIL-B-5087.

3.3.13 Joining Methods. No rolling, spinning, staking, press fits, or crimping shall be used as the primary means of joining detail parts or subassemblies.

3.3.14 Retainer Rings. No retainer rings or snap rings shall be used in the LFV.

3.4 Design. The design covers the following subsystems of the LFV:

a. Stability augmentation

b. Propulsion

c. Instrumentation control and power

d. Landing gear

e. Structure

3.4.1 Stability Augmentation Subsystem (SAS).

3.4.1.1 The SAS is composed of the following components:

a. The rotational controller

b. The control unit

c. The engine gimbal actuation system

d. Rate gyro package

3.4.1.2 Performance Requirements. The SAS shall perform the following functions:

a. Accept attitude rate commands from the pilot in pitch, yaw, and roll axes.

b. Gimbal engines so as to produce a vehicle angular rate which matches the command input and to permit stable manuevering of the vehicle.

c. Drive certain displays.

3.4.1.2.1 Primary Performance Requirements. The primary requirement of the SAS is to complete the rate and attitude-hold feedback loops. The outputs represent three-axis attitude rate commands which are summed with rate gyro outputs within the control unit to produce rate error signals. Rate gyro signals shall be integrated and transformed to produce the attitude meter drives. The engine thrust failure sensors are inputs to logic which determines when one of the four engines should be shut off. The failure information is displayed as a light on the panel.

3.4.1.2.2 Secondary Performance Requirements. The control unit shall accept outputs from the accelerometer, rate gyros, and engine-thrust-failure sensors. These data shall be used in forming display drive signals. The accelerometer signal produces a thrust-to-weight ratio meter drive. Rate gyro signals shall be integrated and transformed to produce the attitude meter drives.

3.4.1.3 Interface Requirements. The SAS interfaces with the pilot, the power supply, the propulsion system, the displays, and the pressurant system.

3.4.1.4 Design and Construction Requirements

3.4.1.4.1 Electrical Power. All components of the SAS will use 28 volts dc (25-31 vdc) as basic power. Within the control unit, power will be converted to all ac voltages required.

3.4.1.4.2 Rotation Controller. The rotation controller shall consist of a spring-restrained hand grip which is free to move in either direction

about each of three orthogonal axes corresponding to pitch, roll, and yaw of the vehicle. Each axis shall include the switches and transducers necessary to initiate control commands, either attitude rate or attitude hold. Proportional control shall be provided by rotational variable differential transformers in each axis which generate output voltages proportional to the angular displacement of the grip. At approximately 1/4 degree in each axis, the detent switch shall switch from the attitude hold mode to the rate command proportional mode. The detent switches produce 28-vdc signals around the neutral stick position and zero voltage beyond 1/4 degree.

3.4.1.4.3 Control Unit. The control unit shall contain electronics necessary to drive the actuators and part of the displays. As a component in the stabilization loop, the control unit shall accept two rate commands from each of the three axes of the rotation controller. The breakout signals from the rotation controller indicate neutral controller position within ±0.25-degree and result in the attitude hold loop closure and activation within the control unit. Two sets of rate gyro signals in each axis shall provide the feedback for the rate stabilization loop. These signals shall be integrated and used in the attitude hold loop. The command logic shall form the redundant commands for each actuator. Only one of the command sets shall be used at a time; the push-to-talk switch on the rotation controller shall provide a redundant system select switch to switch actuator command systems.

3.4.1.4.3.1 Sensors. The command inputs shall be summed with the negative feedbacks from the actuator position transducers to provide error signals which are amplified by the servo amplifiers and sent to the actuators. The display drive function of the control unit shall consist of three parts: (1) the thrust-to-weight ratio drive, (2) the thrust failure indicators, and (3) the attitude angle drives. An accelerometer mounted in the vertical body axis shall sense the ratio of thrust to mass, between 1.2 and 19 feet per second squared. The control unit shall divide the accelerometer signal by lunar gravity, resulting in thrust to weight ratio. Strain sensors located on the engine mounts shall measure individual engine thrust. The thrust signals shall then be summed and divided by four within the control unit to develop the average thrust of one engine. An error signal for each engine shall be generated by subtracting each signal in turn from the average. If the thrust of one engine falls below or rises above the average by a predetermined amount, the control unit shall actuate the proper indicator on the display panel.

3.4.1.4.4 Rate Gyro. The rate gyro signals shall be transformed by an Euler rate matrix using the sequence roll, pitch, yaw from the body axes

to the Euler axes. The integrals of the Euler rates are to be displayed as vehicle attitude. The net error at the display meters in each axis shall be ±3 degrees. The following general ground rules shall control the design of the rate gyros:

a. Six single-axis rate gyros shall be used as two 3-axis redundant sets. Each of the two sets should be environmentally isolated. The maximum nominal angular rates of the vehicle are ±10 degrees/second about any axis.

3.4.1.4.5 Mechanical System. The engine gimbal actuation system shall convert electrical signals to actuator rod translations.

3.4.1.4.6 Throttle Hand Controller. The thrust levels of the engines shall be controlled when the throttle is operated by the pilot's left hand. The throttle shall not include a single point failure and shall be capable of individual engine shutoff. The throttle shall be capable of being rotated 150 degrees and providing a sensitivity for a throttle ratio of 5.3 to 1. The control shall be capable of shutting off all engines simultaneously.

3.4.2 LFV Propulsion Subsystem

3.4.2.1 Propellant and Pressurant. The LFV propulsion system shall employ propellant remaining in the lunar module (LM) descent propulsion system. It shall use nitrogen tetroxide (NTO) as oxidizer and Aerozine 50 (50 percent hydrazine, 50 percent unsymmetrical dimethylhydrazine (A-50)) as fuel. Nominal usable propellant loading of the LFV shall be 300 pounds at an oxidizer/fuel mass ratio of 1.5 to 1. Pressurant shall be helium in accordance with MIL-P-27407.

3.4.2.2 Mission Duty Cycle. The LFV propulsion system shall be designed to perform a minimum of five reference sortie flight profiles as defined in the system specification, with propellant refueling and helium tank replacement before each sortie.

3.4.2.3 Nominal Maximum Thrust. The nominal maximum thrust shall be considered to be the simultaneous operation of four rocket engines each operating at 75 percent of the maximum thrust defined in 3.4.2.7.4.

3.4.2.4 Operability.

3.4.2.4.1 Reliability. The LFV propulsion system shall have as a design goal the reliability of the following. A probability of .998 of successful completion of a single mission as defined in 3.4.2.2, given a successful refueling operation and preflight observation of a satisfactory system operation.

3.4.2.4.2 Maintainability. The LFV propulsion system shall not be designed for maintenance and repair at the launch site (i.e., while stowed in the LM). When the LFV is removed from the LM and deployed on the lunar surface, it shall be possible to check out propulsion subsystem components without disturbing other LFV subsystems. Maintenance on the lunar surface shall be limited to charged helium tank assembly replacement.

3.4.2.4.3 Useful Life. The propulsion system shall have a shelf life of three years with normal preflight checkout, a service life (after initial propellant servicing on the moon) of 14 days, and dry lunar storage life as required by the system specification.

3.4.2.4.4 Environmental. The propulsion subsystem shall be capable of meeting environmental requirements of the LFV system specification.

3.4.2.4.5 Human Performance. Components that must be operated by an astronaut in a pressure suit on the lunar surface shall be designed for ease of operation. These operations shall include:

a. Helium tank removal and replacement, pressure and dust cap removal, and coupling engagement.

b. Propellant fill and vent coupling engagement and disengagement, including placement and removal of pressure caps or dust caps on or from disengaged half couplings.

c. Activation of manual helium or propellant valves open or closed.

3.4.2.4.6 Safety. The propulsion system shall be designed to meet the general safety standards of the LFV system specification. In addition, the following safety precautions shall be taken:

a. Components such as couplings to be operated by astronauts on the lunar surface shall receive special evaluation of the hazards created by component failure modes.

b. The placement of and protection afforded to fluid lines and pressurized components shall be designed to minimize the likelihood of damage by astronaut action or ground personnel within system constraints such as weight and volume.

c. Where like components used in both fuel and oxidizer service cannot be fully inspected before installation, they shall be keyed to prevent interchangeability.

d. The system shall be designed to permit safe operation despite noncatastrophic failure of a single engine, failure open of a single helium regulator, failure open or closed of a check valve element, or overpressurization of propellant tanks caused by thermal excursions.

3.4.2.5 Interface Requirements.

3.4.2.5.1 Schematic Arrangement. The interfaces between the propulsion system and related subsystems shall be as shown in the appendix.

3.4.2.5.2 Detailed Interface Definition. Interfaces within subsystem assemblies and with related subsystems shall be in accordance with the interface control documents.

3.4.2.6 Component Identification. Components of the propulsion subsystem shall be substantially as shown in Figure 14 of the appendix.

3.4.2.7 Specific Requirements. Specific requirements are itemized below for each of the following propulsion subsystem assemblies:

a. Engine thrust mount

b. Engine gimbal assemblies

c. Propellant tanks

d. Helium vessel assembly

e. Pressure regulation assembly

f. Propellant manifold

System pressure and related requirements depend on the type of engine selected. An engine with interregenerative cooling has a higher optimum propellant inlet pressure than an engine with radiation cooling. Where requirements differ, both are shown in the paragraphs below. Those for the radiative engine are in single parentheses; those for the interregenerative engine are in double parentheses. For example, "Pressure shall be (XXX) ((YYY))" for a system with a (radiative) ((interregenerative)) engine.

3.4.2.7.1 Engine Thrust Mount. An engine thrust mount shall be provided which supports four engine-gimbal assemblies, as defined in 3.4.2.7.2, under the environment described in 3.4.2.4.4. Under 100-percent thrust of any three engines or the nominal maximum thrust of 3.4.2.3, the thrust

mount shall not permit the gimbal attachment axis to rotate more than two minutes of arc in any direction.

3.4.2.7.2 Engine Gimbal Assembly. Four engine-gimbal assemblies shall be provided and mounted on the thrust mount of 3.4.2.7.1. Each assembly shall consist of an engine and a gimbal subassembly.

3.4.2.7.3 Gimbal Subassembly. The gimbal subassembly, in combination with actuators, attached as defined in ICD 3.3.2/3.5.5, shall permit rotation of the engine thrust axis of at least ±10.0 degrees about each axis. The gimbal subassembly shall not permit rotation of the engine thrust axis relative to the thrust mount/gimbal attachment axis of more than ±2 minutes of arc in any direction under 100-percent engine thrust in the absence of actuator motion.

3.4.2.7.4 Engine. The engine shall be a liquid bipropellant rocket engine employing the propellants and mixture ratio of 3.4.2.1. Where specified for (radiative) ((interregenerative)) cooling, it shall have the following nominal characteristics:

a. Maximum thrust of 110 lbf and minimum thrust of 18.3 lbf at the limits of the throttle control.

b. Minimum (minus three sigma) delivered specific impulse of 291 lbf-sec/lbm at minimum thrust (steady state).

c. Nozzle exit plane/throat area ratio of 40.

d. Engine inlet pressure no greater than (225) ((285)) psig.

e. Reliable operating life of 1 hour.

f. Provisions for attachment of an engine thrust measurement device at the gimbal ring.

3.4.2.8 Propellant Tanks. One oxidizer and one fuel tank of identical design shall be provided to contain the propellants of 3.4.2.1 plus an allowance at 70 F for ullage gas space. The tanks shall be fabricated from hemispherical titanium alloy forgings in general agreement with the configuration working pressure of (300) ((360)) psig and proof and burst pressures in accordance with system specification. An internal propellant retention/slosh prevention screen system shall be installed before the final girth weld is made. Ports shall be provided at the tank top and bottom for fluid flow.

3.4.2.9 Helium Vessel Assembly. The helium vessel assembly shall consist of a pressure vessel to which a helium connector shall be connected by brazing or welding.

3.4.2.9.1 Helium Vessel. The helium vessel shall consist of a spherical pressure vessel fabricated of fusion welded titanium alloy with associated mounting brackets. The tank shall have an internal volume of 910 ±5 cubic inches and withstand a limit working pressure of 4500 psig. Proof pressure and burst shall be in accordance with system specification design criteria for pressure vessels.

3.4.2.9.2 Helium Connector. A helium connector shall be provided consisting of a tank half and an LFV half capable of the pressures of 3.4.2.9.1. When the tank half is capped by a removable pressure cap, its helium leakage at limit pressure shall not exceed 5 x $10^{-6}$ scc/second. When the two halves are mated (helium vessel assembly installed on the LFV), leakage should not exceed (TBD) scc/second.

3.4.2.10 Pressure Regulation Assembly. The pressure regulation assembly shall receive high pressure helium from the helium vessel assembly of 3.4.4 and deliver regulated helium flow at a nominal (230) ((290)) psig to the propellant tanks of 3.4.2.8. The assembly shall consist of a pressure regulator unit, a helium valve, two check-valve assemblies, two relief valves, and lines and couplings. The assembly shall be mounted in a supporting structure which shall, in turn, be secured to the LFV structure.

3.4.2.10.1 Pressure Regulator Unit. The pressure regulator unit shall consist of a primary and secondary pressure regulator in series. The primary regulator shall reduce the helium supply pressure to a nominal outlet pressure of (235) ((295)) psig. The secondary regulator shall be normally open, but will maintain a nominal outlet pressure of (238) ((298)) psig if the primary regulator fails open.

3.4.2.10.2 Helium Valve. The helium valve shall be a manual fluid valve placed downstream of the pressure regulator unit to provide on/off control of helium flow. A 90-degree rotation of a projecting handle shall be sufficient to actuate the valve from full open to full closed (or vice versa) under the conditions of 3.4.2.4.5. The valve shall be designed for minimum pressure drop when full open.

3.4.2.10.3 Check Valve Assembly. A series-parallel check valve assembly in each helium distribution line shall prevent propellant or vapor mixing. Each assembly shall incorporate four independent check valves in a series-parallel combination. Pressure drop across the check valve at flow equivalent to 3.4.2.3 shall not exceed 5.0 psi at 60 F.

3.4.2.10.4 Pressure Relief Valve. A pressure relief valve shall be provided in each helium distribution line between the check valve and propellant tank. The unit shall consist of a relief valve, a test port, a burst diaphragm, and a filter to remove diaphragm debris. Overpressurization to from (280) to ((340)) psig shall rupture the burst diaphragm, open the relief valve at from (286) to ((346))psig, and vent helium and propellant vapors. The relief valve shall reseat after line pressure has decayed to from (267) to ((327)) psig.

3.4.2.10.5 Helium Lines and Couplings. Helium distribution lines shall be of brazed stainless steel sized to contribute less than a 2-psig pressure drop between regulator and tanks at steady system operation per 3.4.2.3. Provisions shall be made for attachment of pressure sensors. Vent couplings (LFV half) mating with the propellant servicing equipment and a helium coupling (LFV half) mating with the helium vessel assembly shall be provided. A test point shall be provided between the helium valve and the check valves for ground checkout.

3.4.2.10.6 Propellant Manifold. The propellant manifold shall consist of propellant filters, propellant valves, and lines and connectors.

3.4.2.10.6.1 Propellant Filters. A filter shall be provided in each bipropellant distribution line. The filters shall retain particles above a nominal size of 15 microns and shall cause a pressure drop, when clean, of no more than 1.0 psi.

3.4.2.10.6.2 Propellant Valves. A manual propellant valve shall be provided in each propellant distribution line to provide on/off control of propellant flow. A 90-degree rotation of a projecting handle shall be sufficient to activate the valve from full open to full closed (or vice versa) under the conditions of 3.4.2.4.5. The valve shall be designed for minimum pressure drop when full open.

3.4.2.10.6.3 Propellant Lines and Couplings. Propellant distribution lines shall be of brazed stainless steel sized to contribute less than a 5-psig pressure drop between propellant tanks and engine valve inlet at propellant flow equivalent to 3.1.1.3. Fill couplings (LFV half) mating with the propellant servicing equipment shall be provided.

3.4.3 Instrumentation, Control, and Power Subsystem. The LFV shall have a minimum of instruments (panel displays) for safe flight. The LFV shall include those instruments tabulated below.

| Instrument | Type | Operation |
|---|---|---|
| Thrust-to-weight ratio | Linear meter | Electrical |
| Pitch-and-roll indicator | Linear meter | Electrical gyro |
| Azimuth indicator | Circular meter | Electrical gyro |
| Engine status | Light | Electrical |
| Engine cutoff control | Cable | Mechanical |
| Touchdown indicator | Light | Electrical |
| Oxidizer quantity | Optics meter | Fiber optics |
| Fuel quantity | Optics meter | Fiber optics |
| High-pressure indicator | Linear meter | Electrical |
| Low-pressure indicator | Linear meter | Electrical |
| Battery status indicator | Linear meter | Electrical |
| Timer | Digital | Electrical |

3.4.3.1 Batteries. The instrumentation shall utilize as a power source two batteries protected so as to provide redundant sources. A battery status indicator shall be provided with a circuit breaker bar that will enable the pilot to regain the power from either battery once the circuit breaker is tripped.

3.4.4 Landing Gear Subsystem

3.4.4.1 General Design Requirements. The landing gear subsystem (LGS) shall consist of an integral leg frame from which the vehicle body is supported by eight attenuators that control displacements. Four legs shall be provided with nonarticulated landing pads.

3.4.4.2 Lunar Capability. The LGS shall be capable of landing on maria or highlands and surfaces with slopes up to 10 degrees as well as on soil bearing pressure from 8 to 20 psi. The LGS shall be capable of supporting the vehicle on surfaces with hidden rocks and boulders of sufficient size to cause tripping and stable enough to prevent toppling under this condition. The LGS shall provide a 20-degree margin from ventral stability point. Rebound shall not exceed 2 feet after landing.

3.4.4.3 LGS/Pilot. The pilot shall be attenuated by the landing gear to 8 g's in a normal direction and 4 g's in a lateral direction.

3.4.4.4 Pilot Stability Control. The performance shall be as specified utilizing the limits of pilot operation/perception capability and the precision of the stabilization and control system (SCS), except initial touchdown conditions shall not exceed the following:

| | |
|---|---|
| Attitude | ±10.0 degrees |
| Attitude rate | ±3.0 degrees/second |
| Vertical velocity | 7.0 fps |
| Horizontal velocity | 3.5 fps |

3.4.4.5 Attenuator Requirements.

3.4.4.5.1 Load Rating. The applied load rating shall be 900 pounds nominal. The preload shall be 140 pounds.

3.4.4.5.2 Coefficients. The average spring coefficient shall be 4900 lb/ft. The average damping coefficient at 70 F shall be compression 7.3 (lb-sec $^2$/ft $^2$); extension 109 (lb-sec$^2$/ ft $^2$). The maximum stroke shall be 4 inches, with a nominal stroke of 2.5 inches.

3.4.4.5.3 Fluids. The attenuator system shall utilize the following fluids:

a. Hydraulic fluid shall be Dow-Corning F-4029 compressible silicone fluid.

   Hydraulic pressure rating:

   | | |
   |---|---|
   | Operating max | 15,000 psig |
   | Proof | 22,500 psig |
   | Burst | 30,000 psig |

   Hydraulic leakage: $10^{-7}$ cc/sec

b. Pneumatic fluid shall be helium; the pneumatic pressure rating shall be:

   | | |
   |---|---|
   | Operating | 1800 psig |
   | Proof | 3900 psig |
   | Burst | 6000 psig |
   | Leakage | $1 \times 10^{-6}$ lb/sec |

3.4.4.5.4 Environment. The attenuator shall be capable of withstanding the following environmental conditions:

Temperature (F)
Storage - 65 to 195
Operational 0 to 125
Pressure - Atmosphere to $10^{-8}$ Torr
Vibration - 80 to 500 Hz at .05 $g^2$/Hz
Shock (qual test) 30 g's 10 ms rise time, 6 tests
Cycle life:
Operating 200
Qualification test 1000

3.4.5 Structural Subsystem

3.4.5.1 General Design Requirements. The structural subsystem shall consist of the upper body structure, load pans, seat and secondary structure such as console and controller arms, engine-mounting provisions, and subsystem mounting bracketry.

3.4.5.2 Factors of Safety. Structural factors of safety shall be as defined in Paragraph 3.2.1 of the Lunar Flying System Specification.

3.4.5.3 Environment and Load Requirement. Environmental and loading requirements for each mission phase are as defined in paragraph 3.1.3.8 of the Lunar Flying System Specification. Operating environments and loadings are to be established from the operations profile and functional requirements of the LFV subsystems.

3.4.5.4 Upper Body Structure. The upper body structure shall comprise two pairs of aluminum box or channel beams forming a rectangular frame through which seat, tanks, load pan, and attenuator loads are carried. Seat travel adjustment tracks integral with the load pan cross beams are to be provided.

3.4.5.5 Load Pans. Standard fore and aft load pans of fabricated aluminum sheeted frame construction and adaptable to government-furnished equipment (GFE) payloads, with a universal tie-down method, shall be provided. Attachment fittings shall permit removal of standard load pans and replacement with mission module load pans matched and integrated with a specific payload.

3.4.5.6 Seat. Seat formed of polyimide or phenolic fiberglass and protected with white thermal paint shall be provided. Seat configuration is to be suitable for the complete range of astronaut anthropometric limits. Provisions for portable life support system (PLSS) support and restraint strap attachments shall be made adjustable as necessary. A foot support and restraint integral with the seat shall be incorporated.

# LUNAR SUPPORT EQUIPMENT CONTRACT
# END ITEM SPECIFICATION

1. SCOPE. This specification defines the requirements for the design, performance, test, and qualification of the lunar support equipment for the lunar flying system.

The equipment is composed of:

a. Propellant servicing equipment

b. Portable electrical and mechanical (E&M) checkout unit

c. Servicing tools

d. Portable remote site takeoff mats

e. Homesite landing and takeoff mat

2.0 APPLICABLE DOCUMENTS. Not applicable.

3.0 REQUIREMENTS. The basic requirement of the lunar support equipment shall be to support the LFV operations on the lunar surface. The requirements specified in the system specification, (i.e., performance allocations, environmental, launch and storage) apply to these items.

3.1 <u>Support Equipment.</u>

3.1.1 <u>Propellant Servicing.</u> The propellant servicing equipment (Ref NR Dwg 2230-101) shall consist of two 50-foot hoses attached to the LM with a shut-off valve sight glass and connector at the LFV end. The first hose shall service the oxidizer tank and the other fuel tank. Two vent lines for attachment to the LFV during servicing shall also be provided.

3.1.2 <u>Portable Electrical and Mechanical Checkout.</u> The portable E&M checkout unit shall consist of a power checkout unit, an electronics/ gyro checkout unit, and a gimbal actuator checkout unit.

3.1.3 <u>Servicing Tools.</u> Servicing tools consist of a 0-to-50-lbm spring weight scale and assorted hand tools to operate valves and disconnects.

3.1.4 Remote Site Takeoff Mats. The portable remote site takeoff mats provide a platform for the return trip to the LM. Weight shall not exceed 2 pounds for four units.

3.1.5 Landing and Takeoff Pad. The homesite landing and takeoff mat provides a platform for sorties away from the LM. Weight shall not exceed 5 pounds.

4. QUALITY ASSURANCE. The quality assurance practices defined in the LFV contract end item (CEI) specification shall govern fabrication and testing of items herein listed.

5. PREPARATION FOR DELIVERY. The preparation for delivery practices defined in the CEI specification shall govern the shipment of items or components of the lunar support equipment (LSE).

6. NOTES. Not applicable.

# TRAINING AND DEVELOPMENT TEST ARTICLES
# CONTRACT END ITEM SPECIFICATION

1. SCOPE. The intent of this specification is to establish the performance and design criteria of the training and development test articles of the lunar flying system.

2. APPLICABLE DOCUMENTS. This section not applicable.

3. REQUIREMENTS.

3.1 Training Articles. The articles required for training shall include the following articles:

a. Mockup

b. 1/6-tethered flight training vehicle

c. Free-flight training vehicle

d. Visual simulator

3.2 Development Test Articles. The articles required for development test shall include the following articles:

a. Engineering mockup (two articles, one house spacecraft article)

b. Structural test article

c. Thermal test article

d. Integrated propulsion SAS article

e. Propulsion breadboard

Articles for c and d above are actual end item LFV's.

f. Landing Test Vehicle

3.3 General Training Requirements. The training shall be divided into three phases and shall include academic and practical-flight training sessions. The first phase shall consist of a general LFV systems and mission familiarization briefings. The second phase shall consist of academic sessions for the presentation of LFV systems functional and operational material and shall be interleaved with practical sessions using an LFV full-scale mockup and visual simulation trainers. The third phase of training shall consist of actual flight exercises with a tethered flight vehicle and a free flight training vehicle. Training manuals shall be prepared and maintained, as required, for the above training phases.

3.4 General-Development Test Articles. The test articles of the LFV system shall be utilized to provide engineering information and facilitate the qualification of the end items.

4. QUALITY ASSURANCE. The quality assurance practices defined in the contract definition instruction (CDI) specification of the LFV shall, to the extent practicable, govern the fabrication of the end items defined herein.

5. PREPARATION FOR DELIVERY. Any article or component of these items requiring delivery either to the contractor or the customer (field site) shall be suitably protected against damage.

6. NOTES. Not applicable.

# APPENDIX: LUNAR FLYING VEHICLE PRELIMINARY DESIGN DRAWINGS

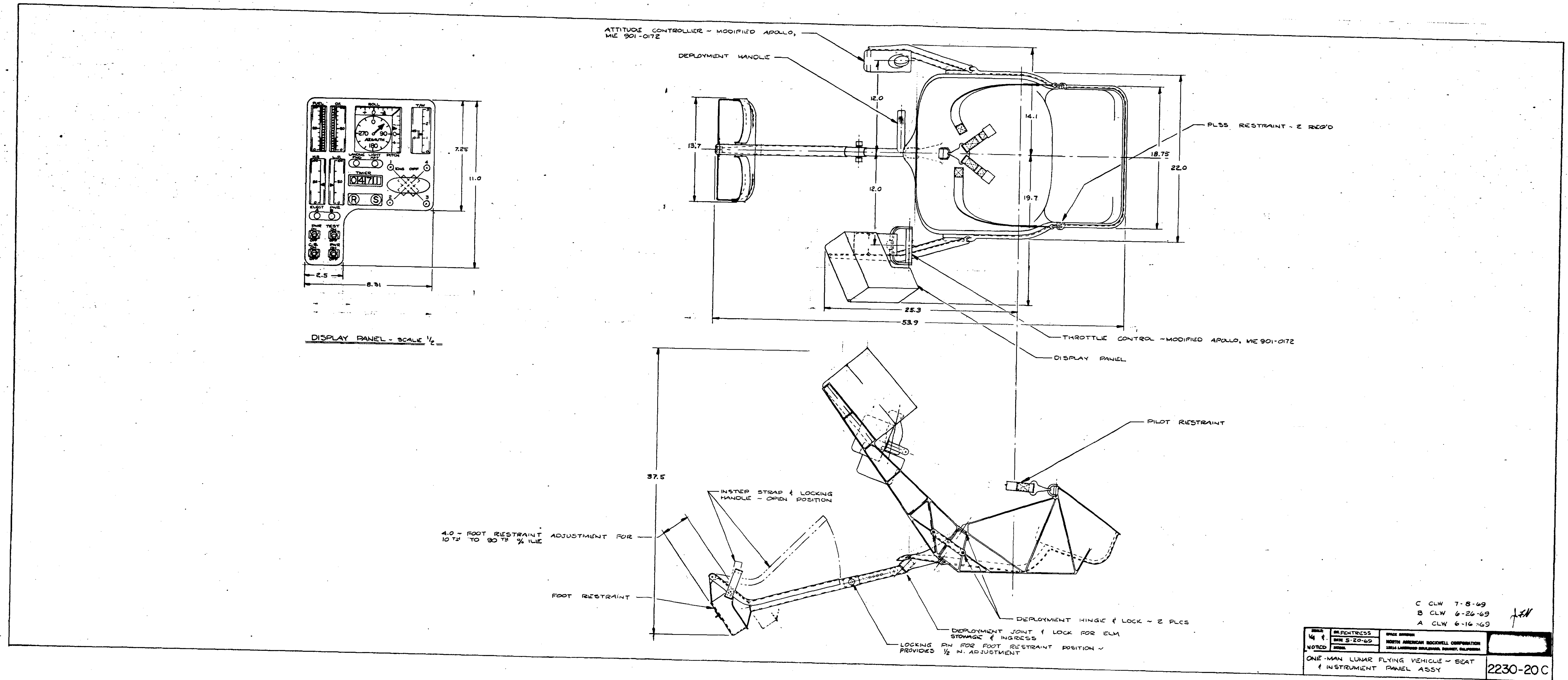
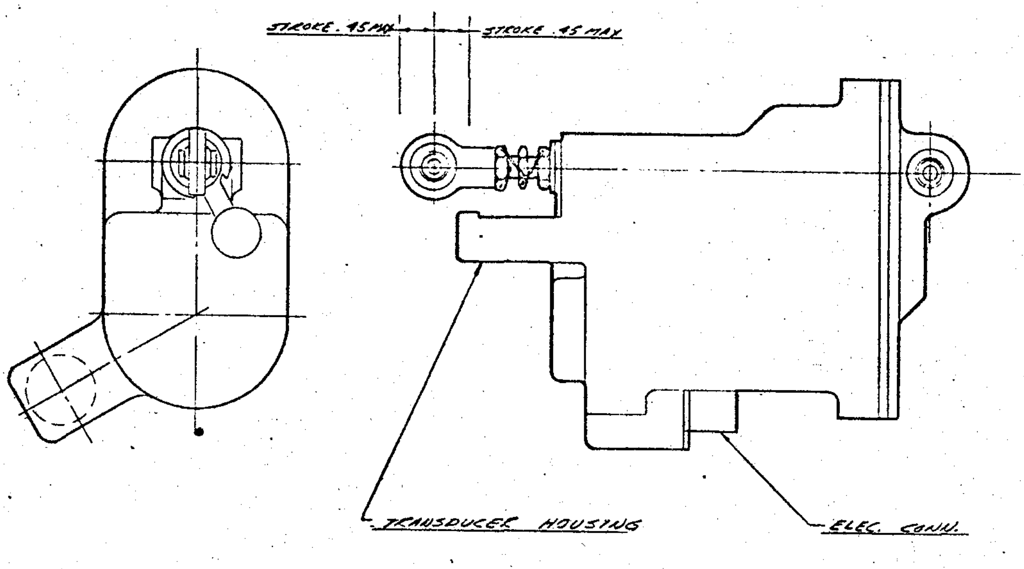


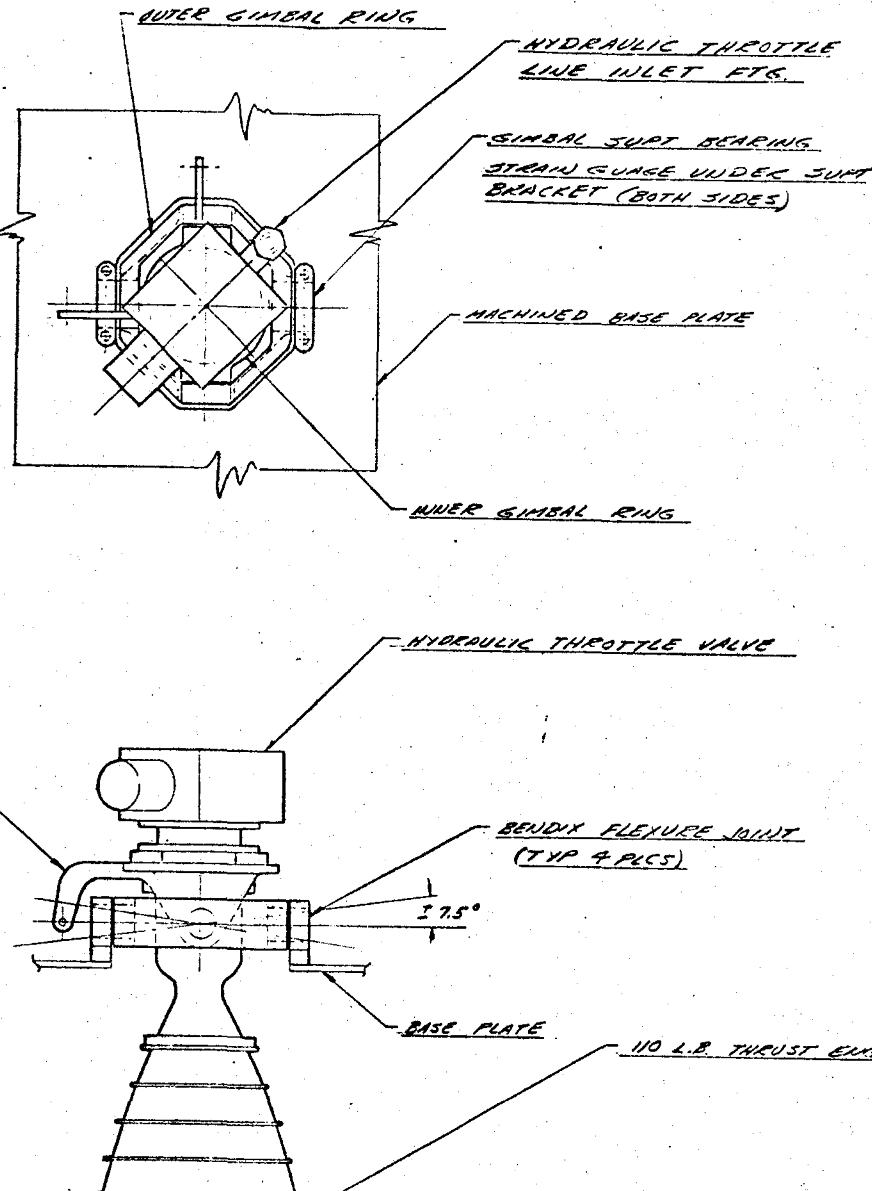

Figure 6. LFV Seat and Instrument Panel Assembly (Drawing 2230-20B)




D.C. GIMBAL ACTUATOR

FULL SIZE

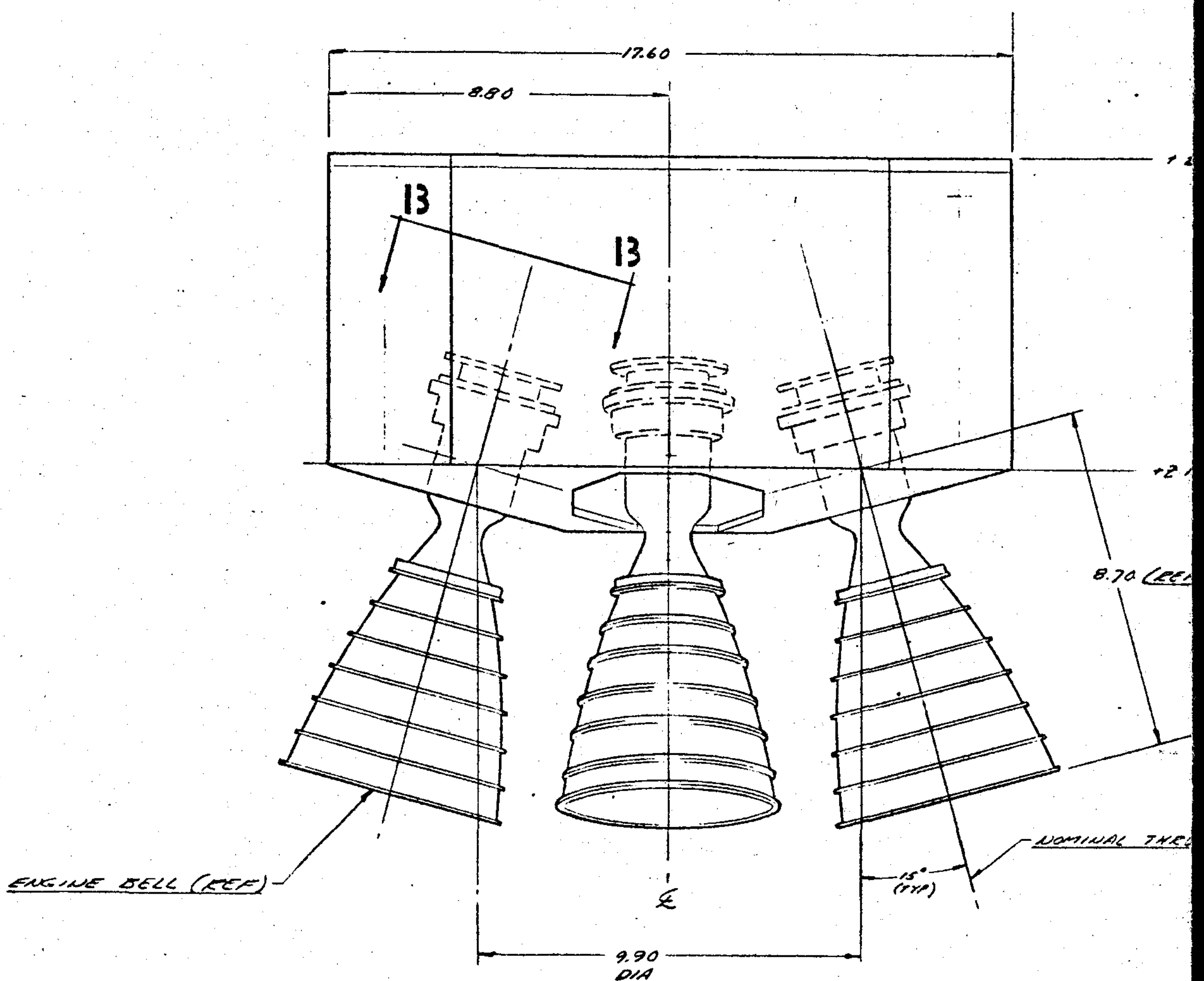
56-1




VIEW B - B

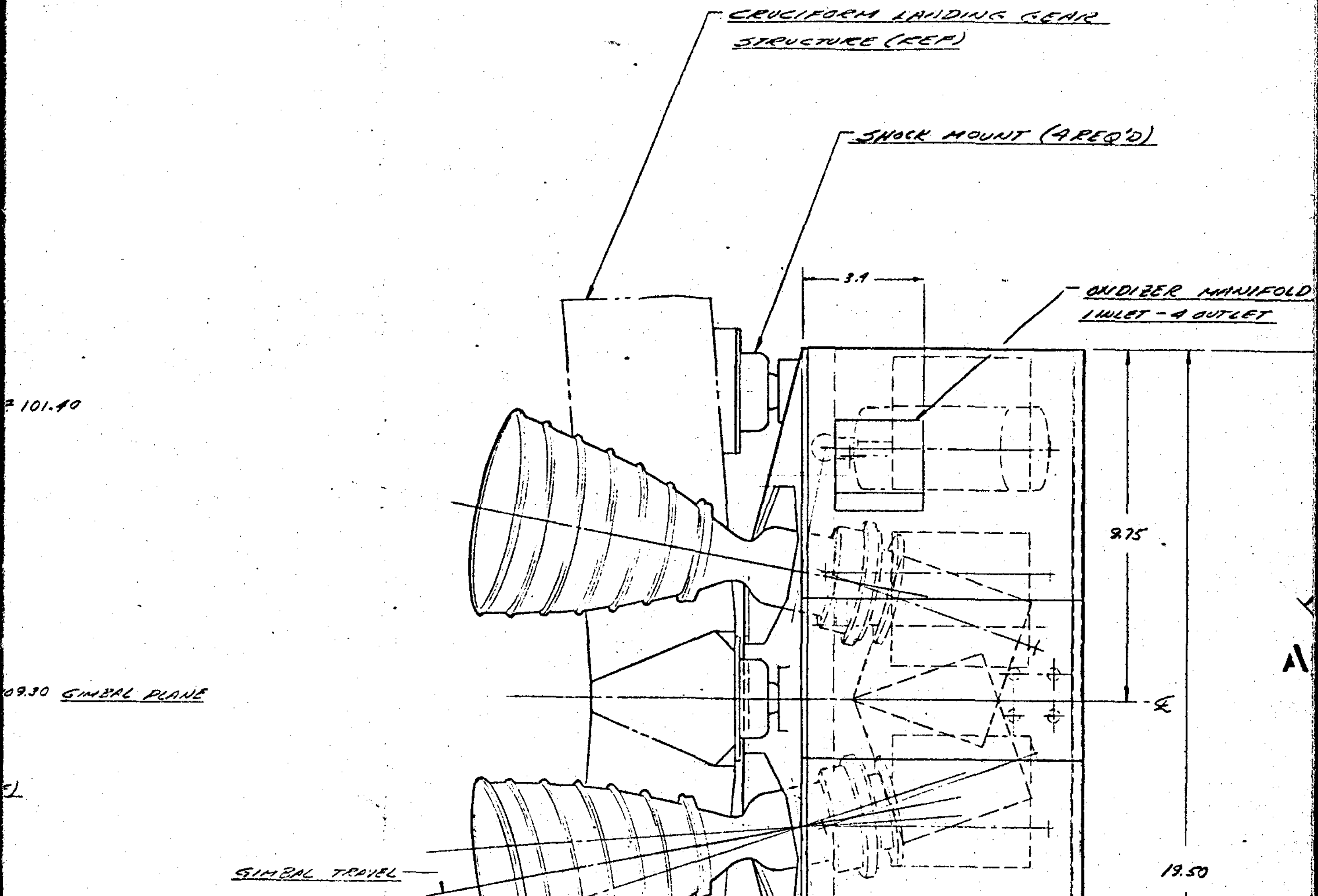
ENGINE & GIMBAL INSTAL & DETAIL

56-foldout #2



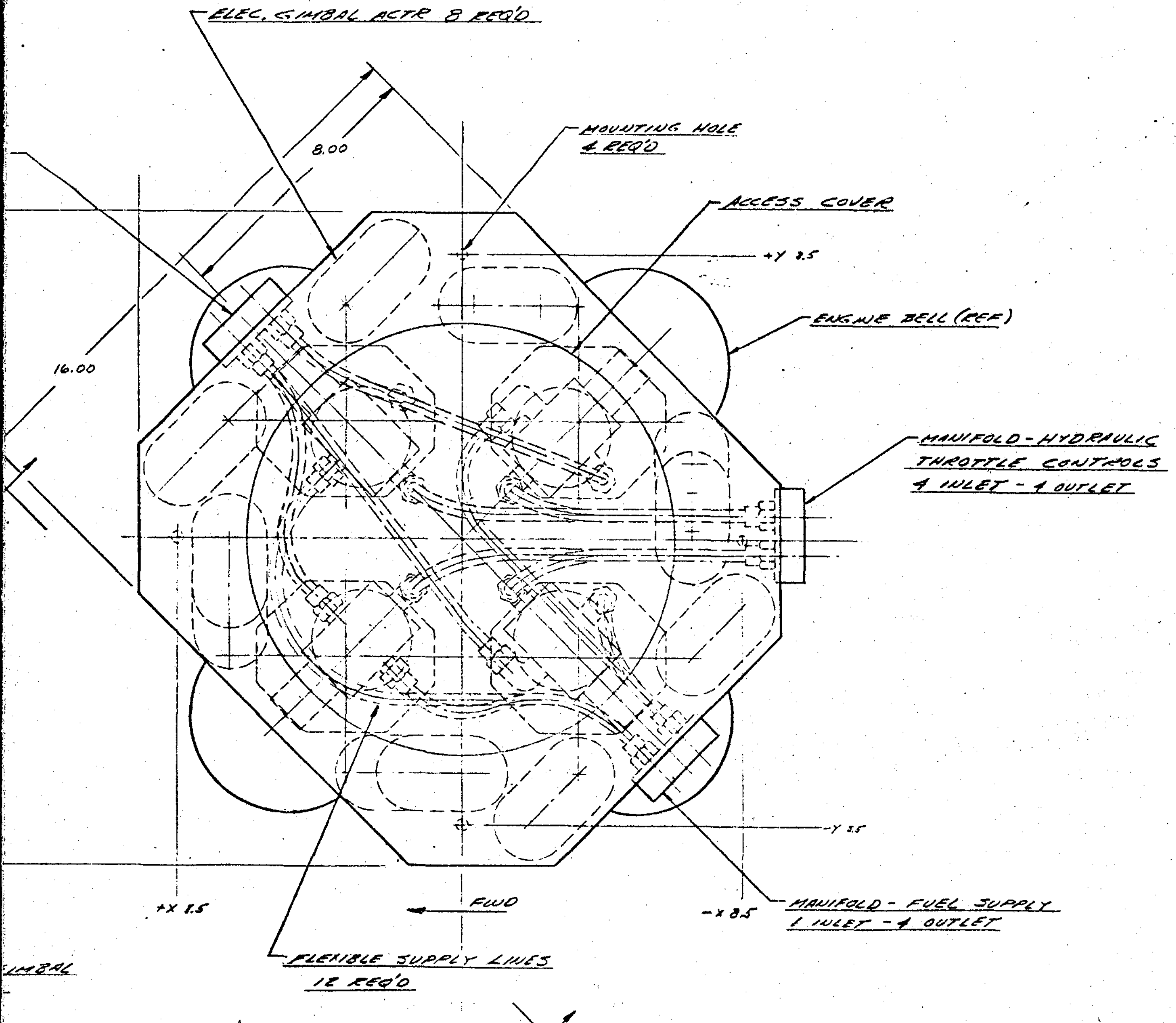

VIEW A-A

56-Foldout #3



CRUCIFORM LANDING GEAR STRUCTURE (REF)
SHOCK MOUNT (4 REQ'D)
3.4
OXIDIZER MANIFOLD
1 INLET - 4 OUTLET
101.40
09.30 GIMBAL PLANE
9.75
19.50
GIMBAL TRAVEL
± 7.5°
IST ANGLE
ELECTRIC
ACTUATOR
Z 109.30
Z 101.40
GIMBAL PLANE
RIVETED SHEET METAL


56 - foldout #4




IMBAL

ONSTRUCTION

Foldout #5

NOTE: M
F

ENGINE SPECIFICATIONS

ENGINE: (NOTE)

| | |
|---|---|
| NOMINAL THRUST | 105 LBS |
| CHAMBER PRESS | 100 PSIA (MIN.) |
| MIXTURE RATIO | 1.5-1 |
| PROPELLANTS | A-50 & $N_2O_4$ |
| SPECIFIC IMPULSE | 293 SECS (NOM.) |
| EXPANSION RATIO | 40:1 (MIN.) |

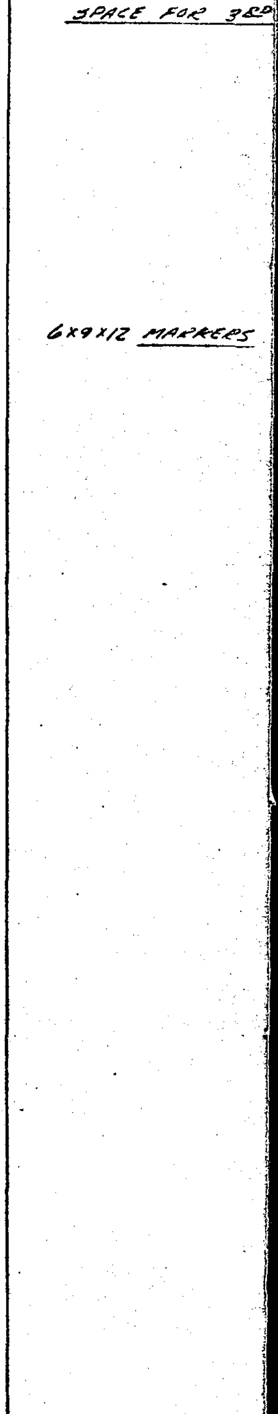
Foldout #6

A 6-25-69 CLW

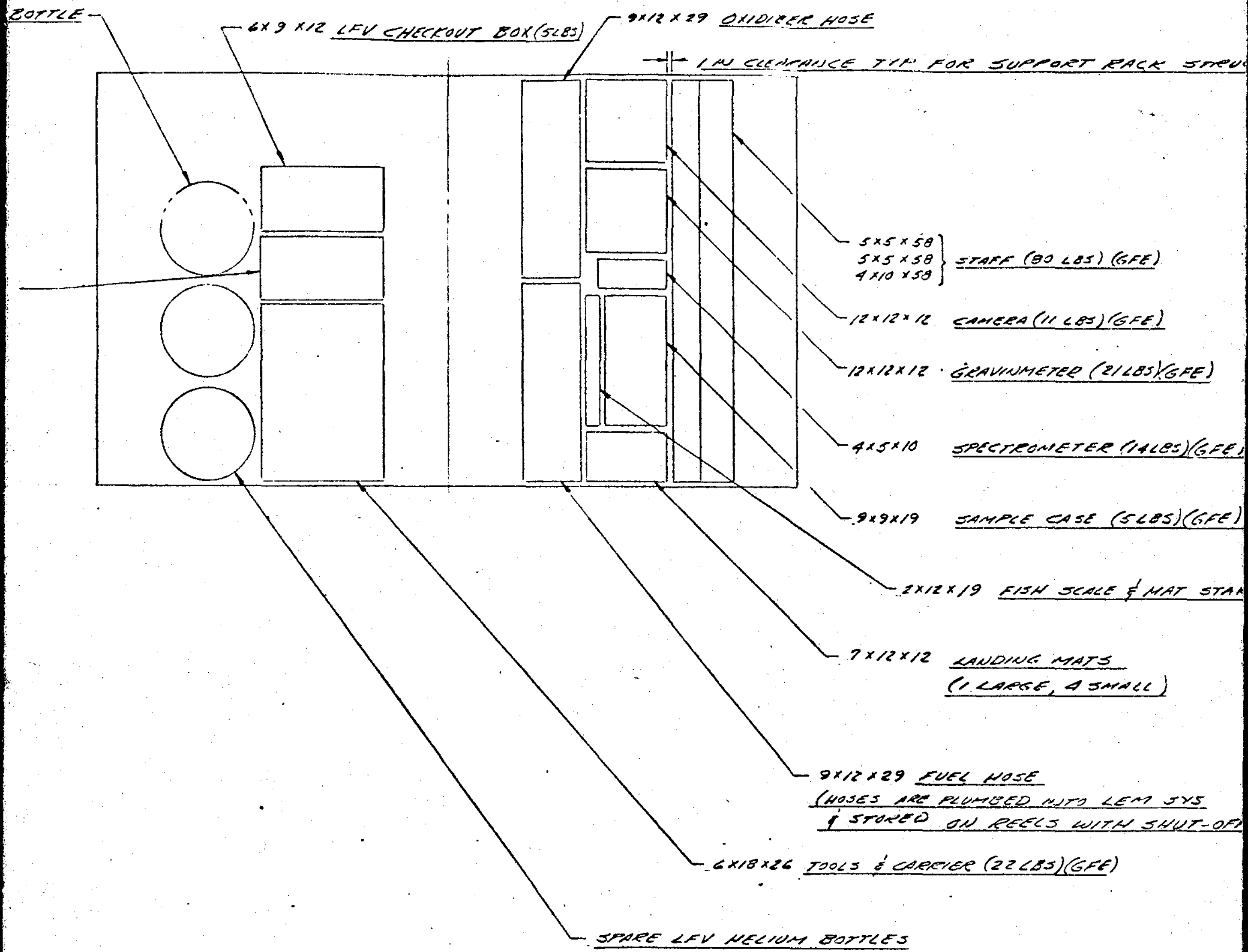
REDUNDANT MODEL RAD SHOWN FOR
PURPOSE OF ILLUSTRATION ONLY

| | | | |
|---|---|---|---|
| SCALE: 1/2 / NOTED | DR. / DATE / MODEL | SPACE DIVISION<br>NORTH AMERICAN ROCKWELL CORPORATION<br>12214 LAKEWOOD BOULEVARD, DOWNEY, CALIFORNIA | |
| | ONE MAN LFV - ENGINE INSTAL.<br>4 GIMBALLED ENGINES<br>SELECTED CONCEPT | | 2230-21A |

Figure 7. LFV Engine Installation - Four Gimballed Engines, Selected Concept (Drawing 2230-21A)




57
foldout #1




VIEW A-A

NOTE: THOSE ITEMS MARKED GFE ARE REP
ITEMS OF SCIENTIFIC EQUIPMENT
IN RFP.

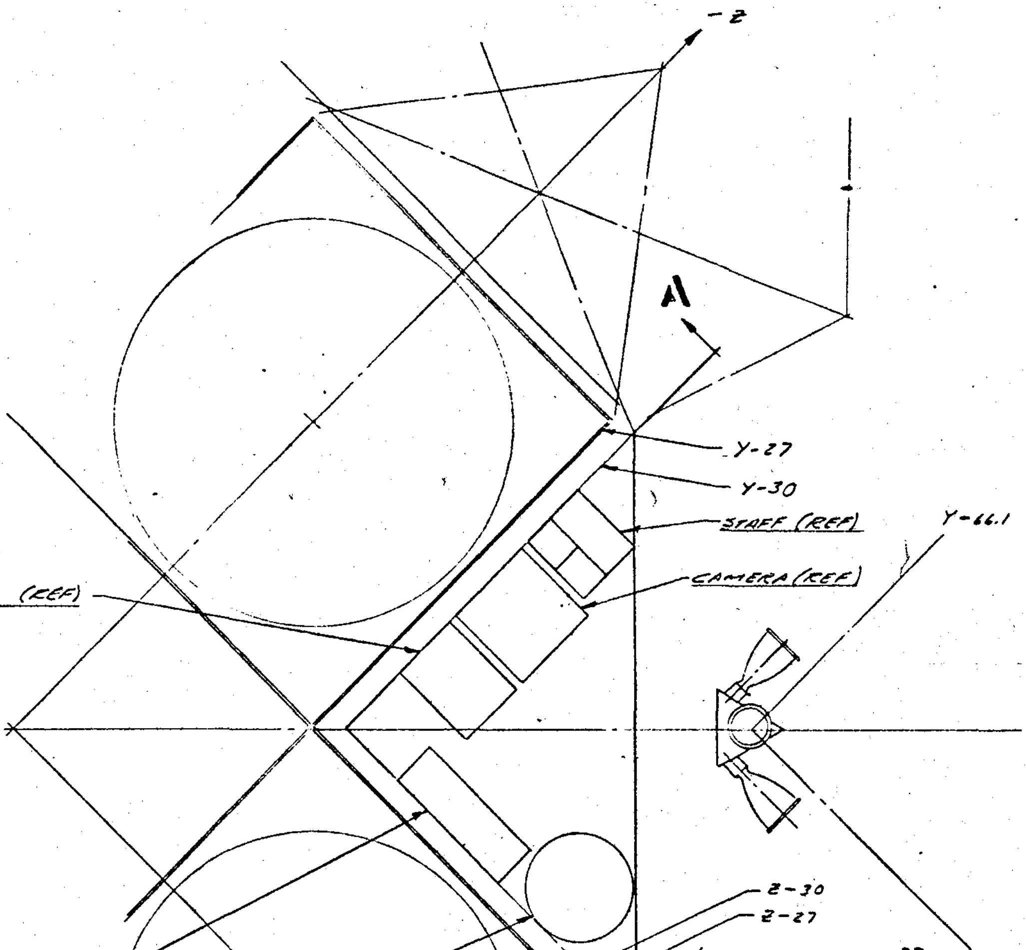
57-foldout #2

ET.

ING TOOL

F VALVES)

PRESENTATIVE
S INDICATED




NOTE: EACH ITE
FROM ITS
RANDOM
INTERFER

57 foldout #3

Space Division
North American Rockwell

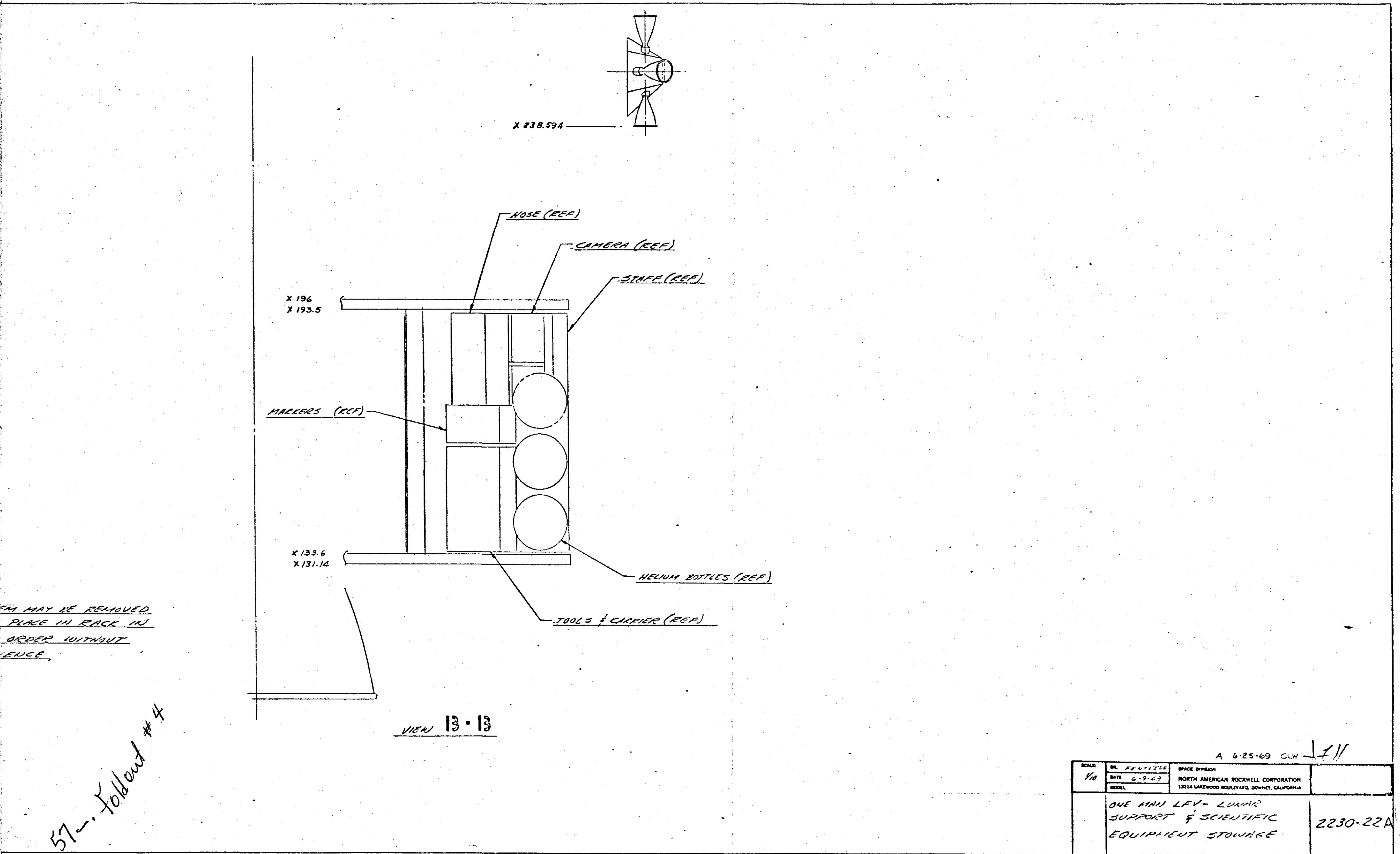
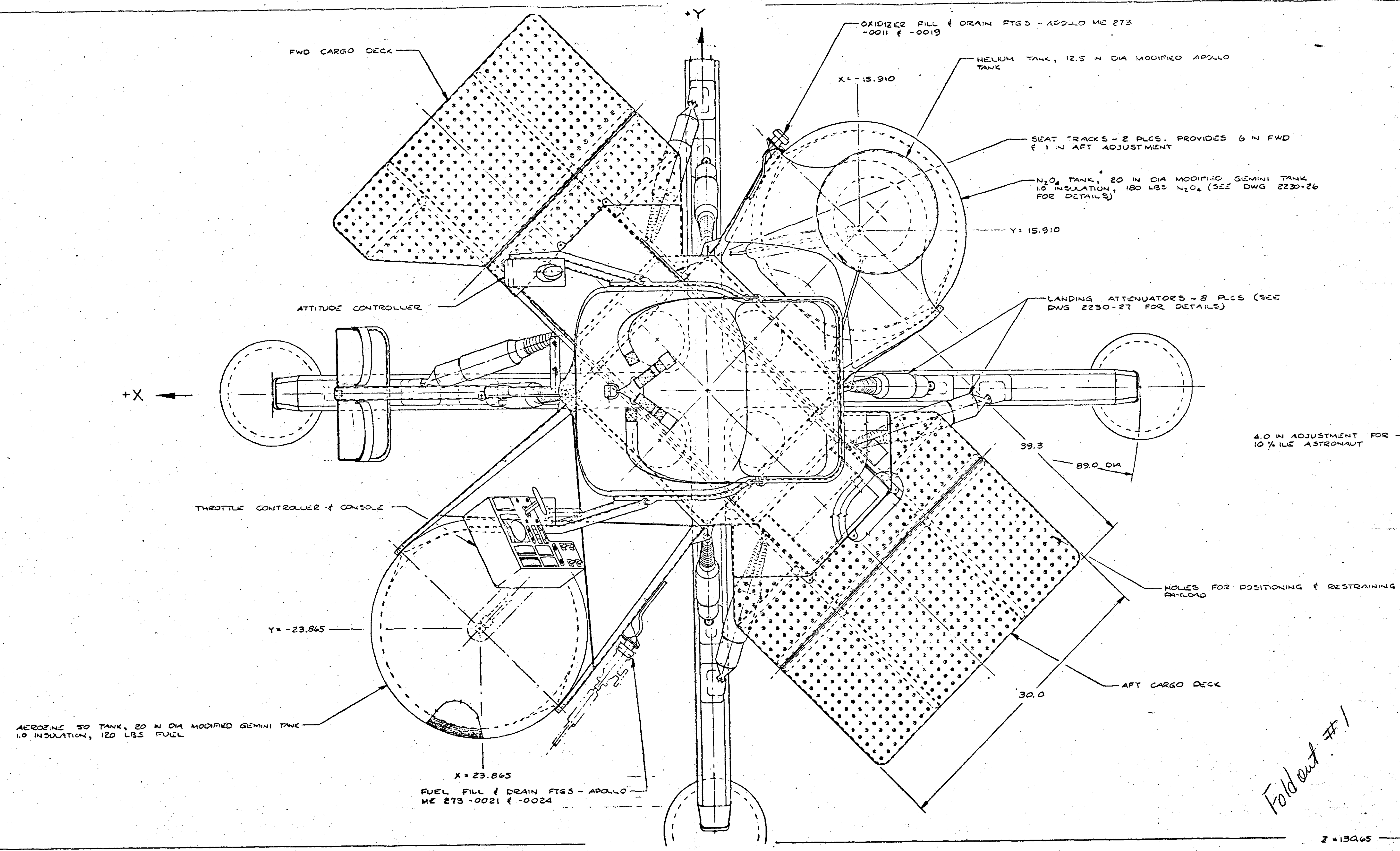



**Figure 8. LFV Lunar Support and Scientific Equipment Stowage (Drawing 2230-22A)**



+Y
+X
FWD CARGO DECK
OXIDIZER FILL & DRAIN FTGS - APOLLO ME 273 -0011 & -0019
HELIUM TANK, 12.5 IN DIA MODIFIED APOLLO TANK
X = -15.910
SEAT TRACKS - 2 PLCS. PROVIDES 6 IN FWD & 1 IN AFT ADJUSTMENT
$N_2O_4$ TANK, 20 IN DIA MODIFIED GEMINI TANK 1.0 INSULATION, 180 LBS $N_2O_4$ (SEE DWG 2230-26 FOR DETAILS)
Y = 15.910
ATTITUDE CONTROLLER
LANDING ATTENUATORS - 8 PLCS (SEE DWG 2230-27 FOR DETAILS)
4.0 IN ADJUSTMENT FOR 10 %ILE ASTRONAUT
39.3
89.0 DIA
THROTTLE CONTROLLER & CONSOLE
HOLES FOR POSITIONING & RESTRAINING PAYLOAD
Y = -23.865
AFT CARGO DECK
30.0
AEROZINE 50 TANK, 20 IN DIA MODIFIED GEMINI TANK 1.0 INSULATION, 120 LBS FUEL
X = 23.865
FUEL FILL & DRAIN FTGS - APOLLO ME 273 -0021 & -0024
Foldout #1
Z = 130.65

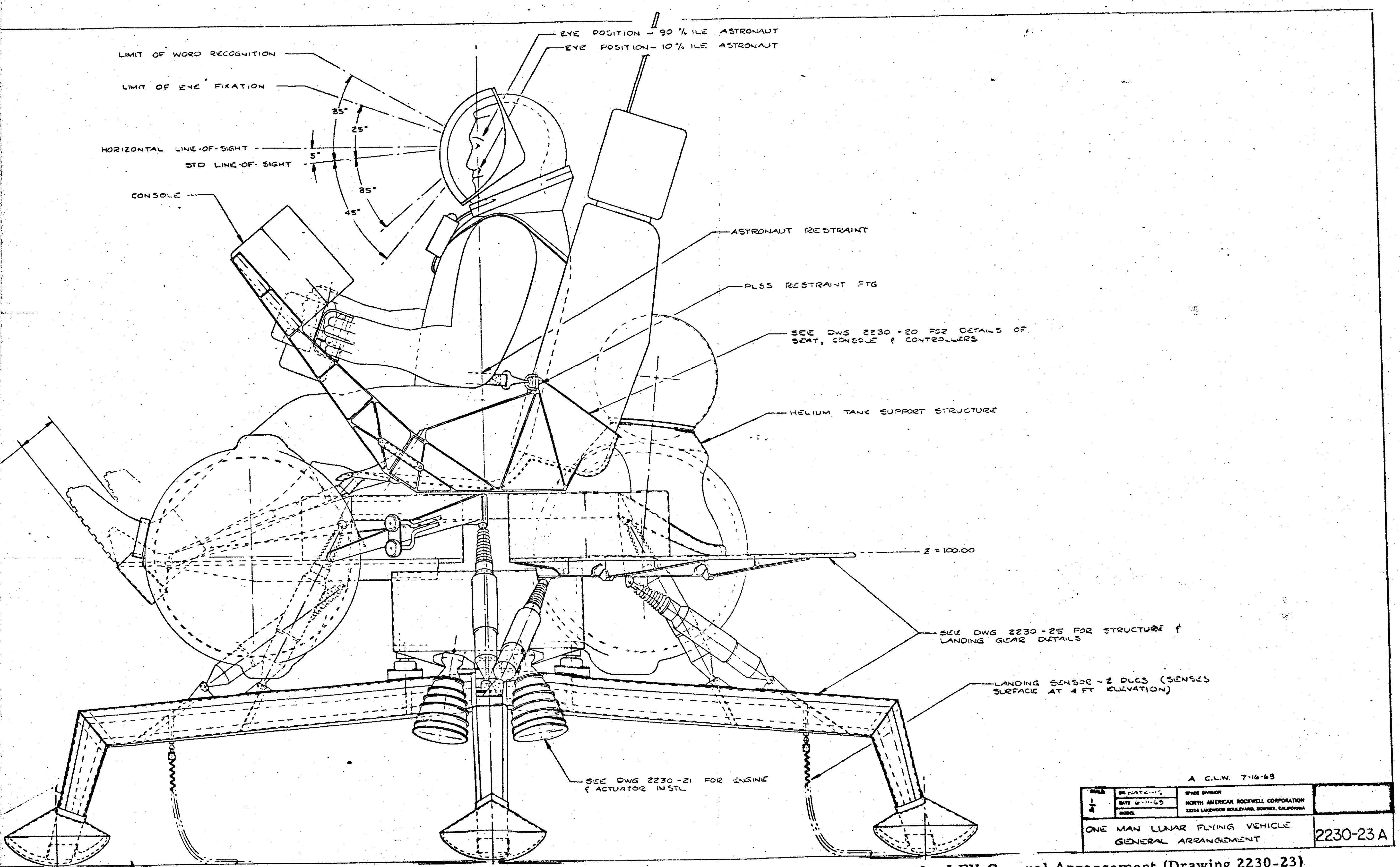
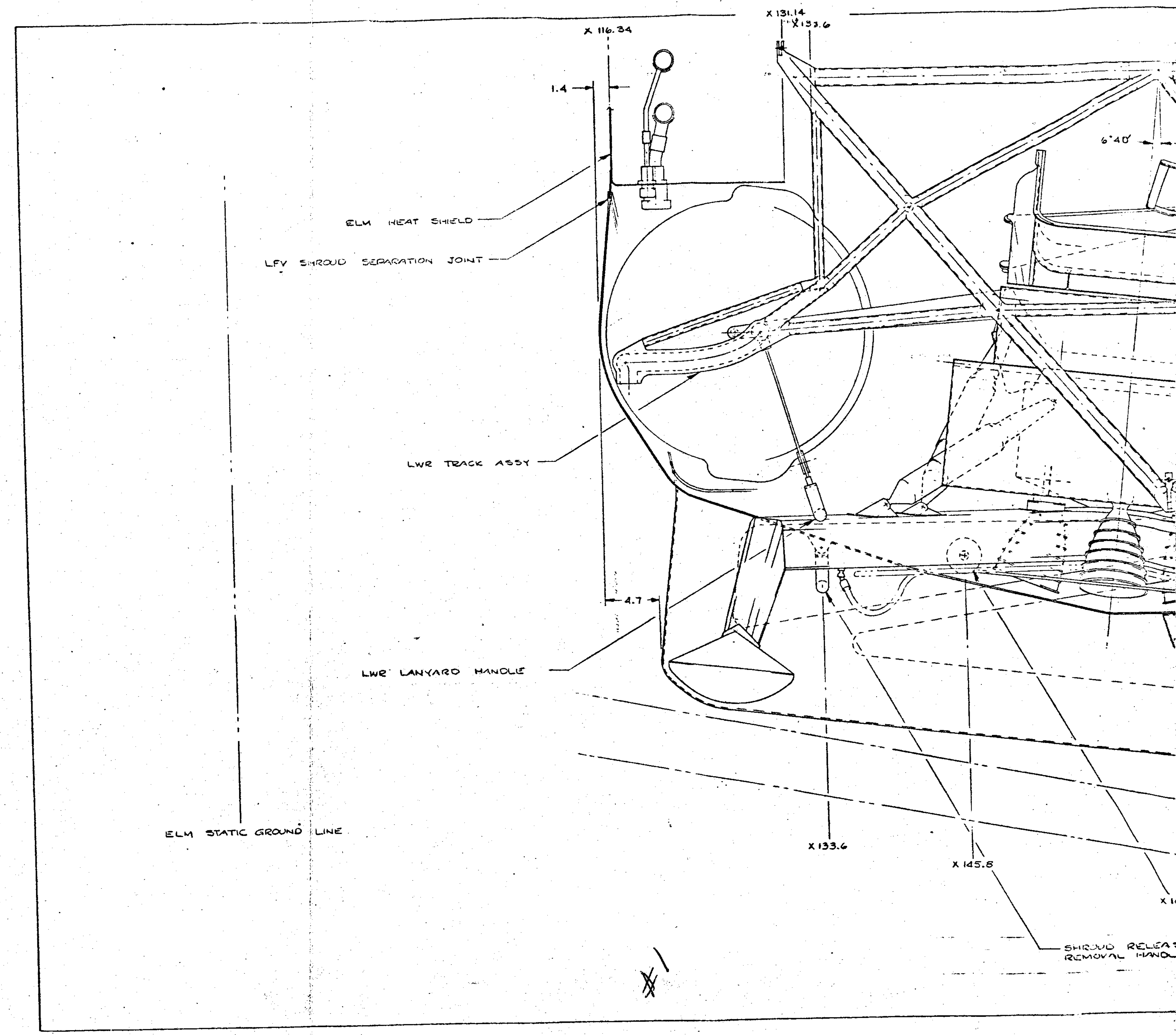
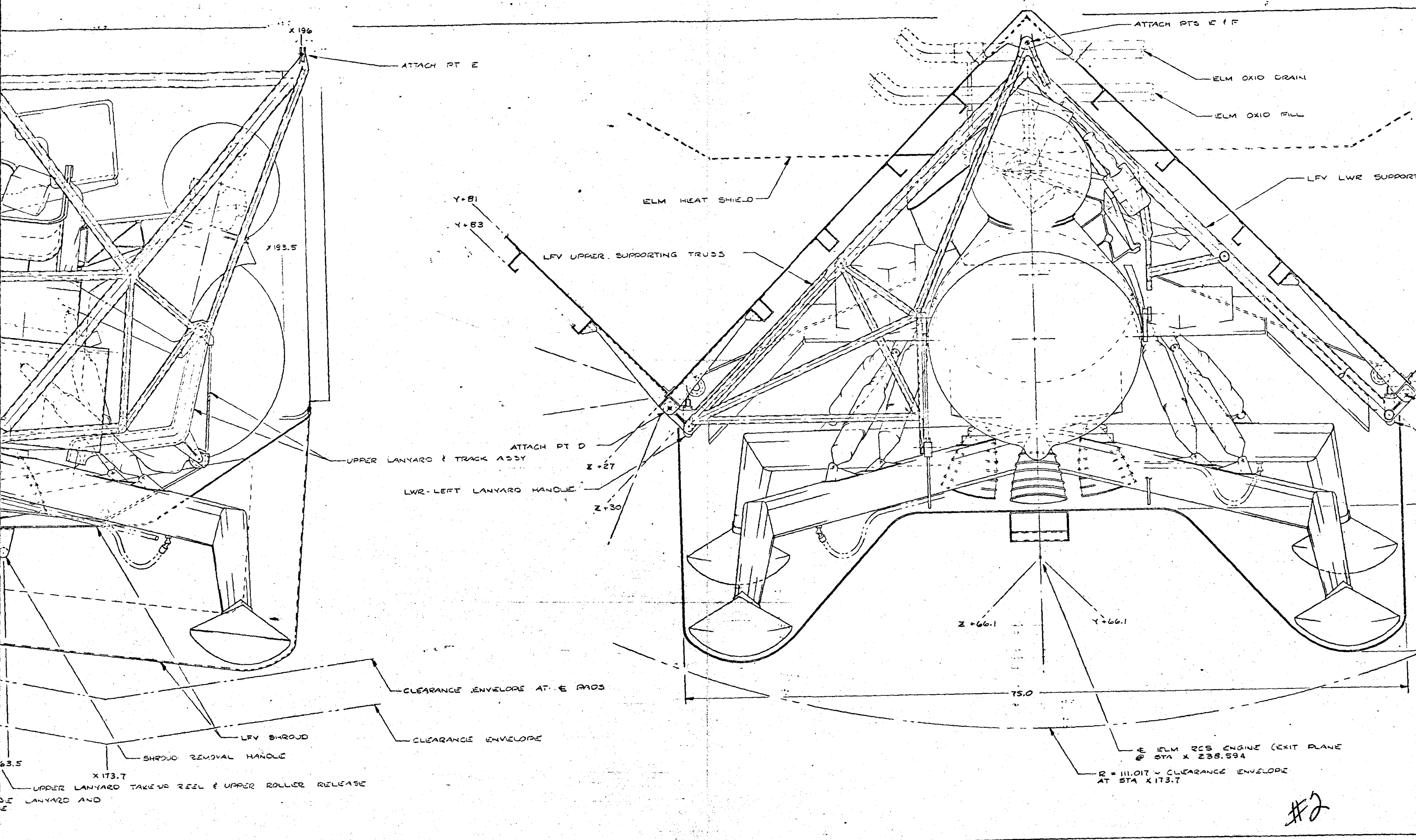



Figure 9. LFV General Arrangement (Drawing 2230-23)



X 131.14
X 133.6
X 116.34
1.4
6.40
ELM HEAT SHIELD
LFV SHROUD SEPARATION JOINT
LWR TRACK ASSY
4.7
LWR LANYARD HANDLE
ELM STATIC GROUND LINE
X 133.6
X 145.8
SHROUD RELEAS
REMOVAL HANDL


X 196
ATTACH PT E
X 193.5
UPPER LANYARD & TRACK ASSY
LFV SHROUD
SHROUD REMOVAL HANDLE
X 173.7
63.5
UPPER LANYARD TAKE UP REEL & UPPER ROLLER RELEASE
LANYARD AND
CLEARANCE ENVELOPE AT ℄ PADS
CLEARANCE ENVELOPE
Y+81
Y+83
LFV UPPER SUPPORTING TRUSS
ELM HEAT SHIELD
ATTACH PT D
Z +27
LWR-LEFT LANYARD HANDLE
Z +30
ATTACH PTS E & F
ELM OXID DRAIN
ELM OXID FILL
LFV LWR SUPPORT
Z +66.1
Y +66.1
75.0
℄ ELM RCS ENGINE (EXIT PLANE @ STA X 238.594
R = 111.017 ~ CLEARANCE ENVELOPE AT STA X 173.7
#2

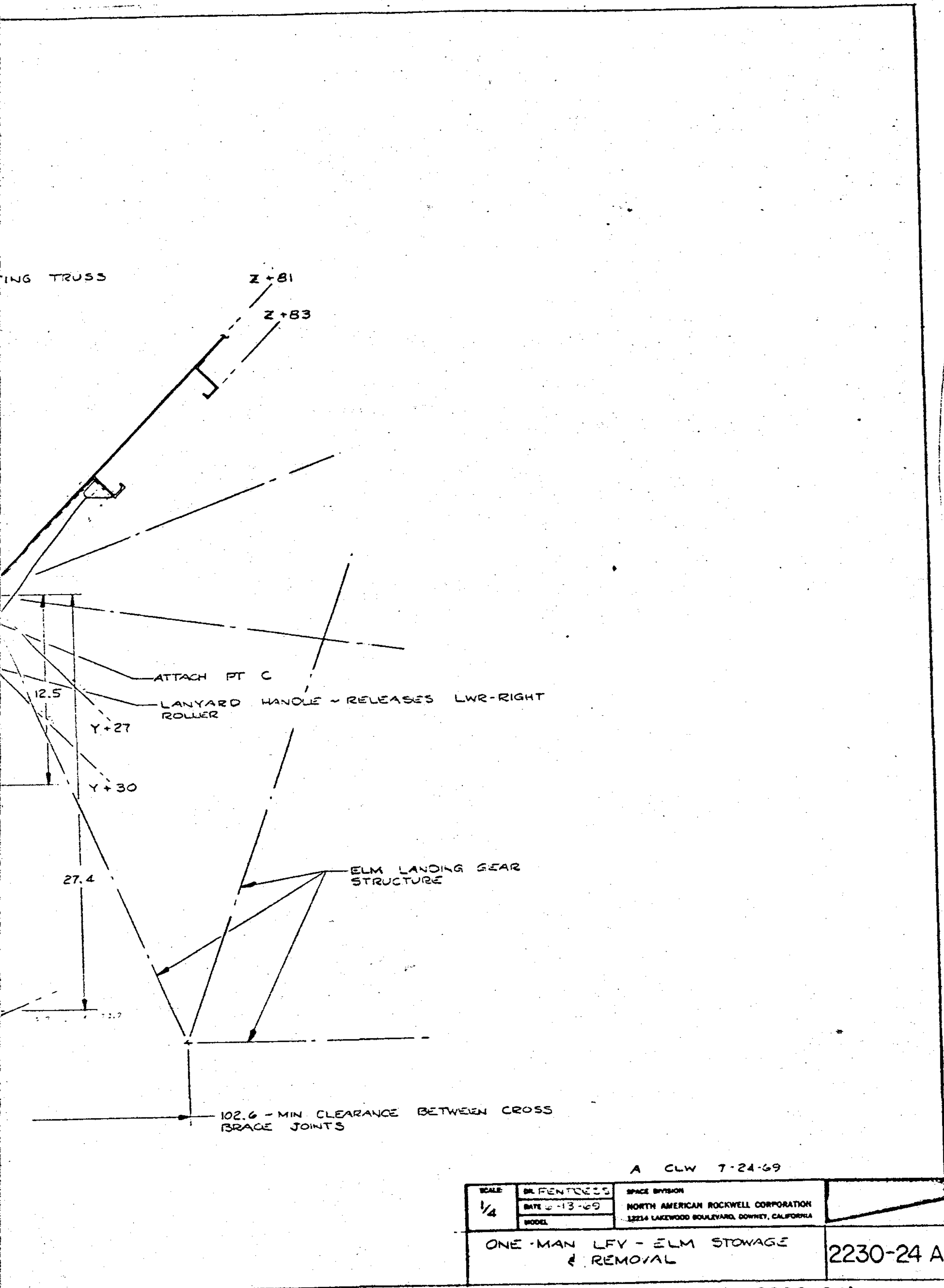
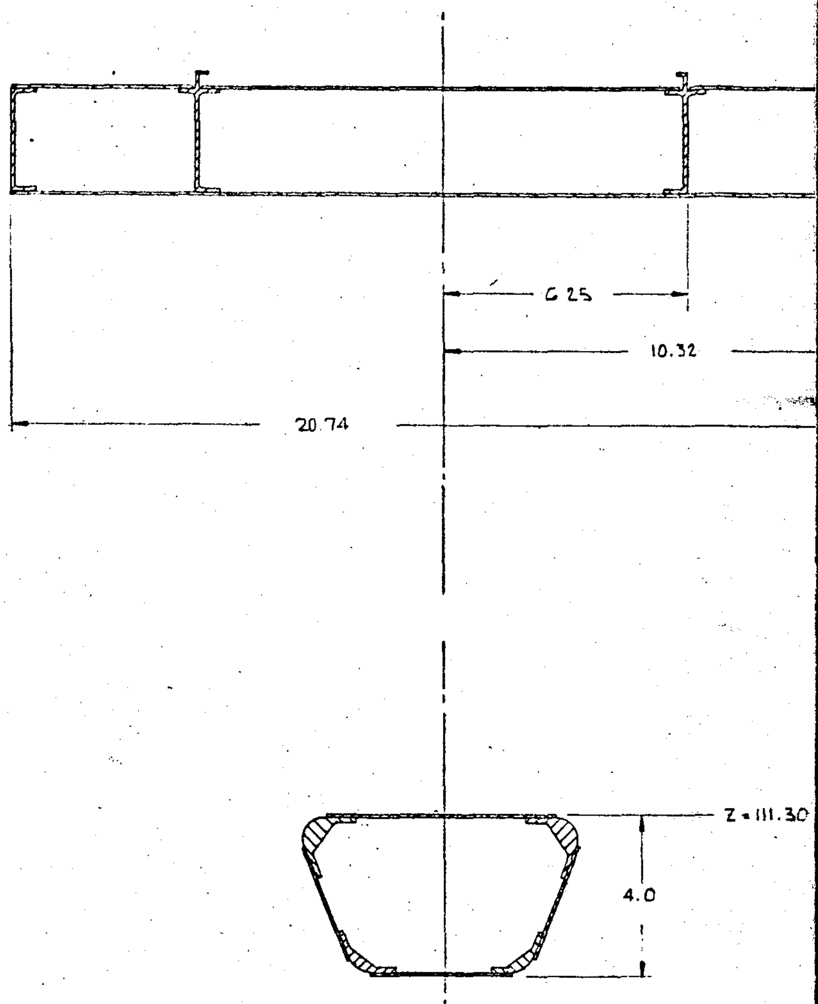



Figure 10. LFV ELM Stowage and Removal (Drawing 2230-24)



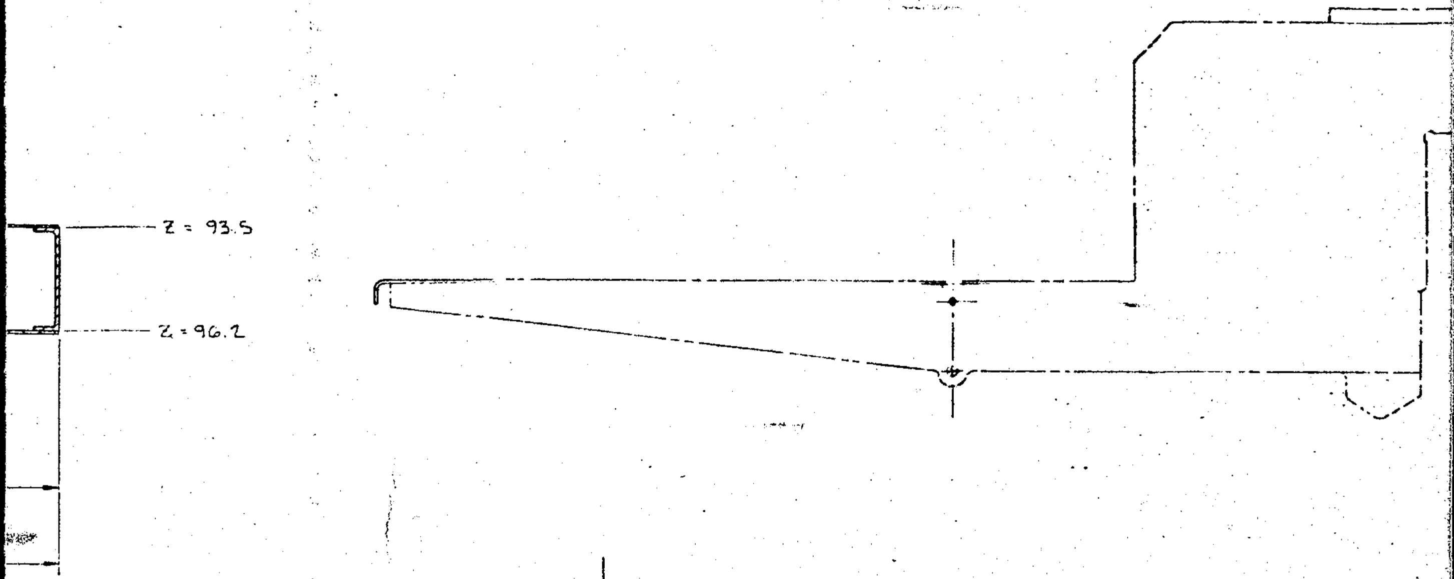
#3

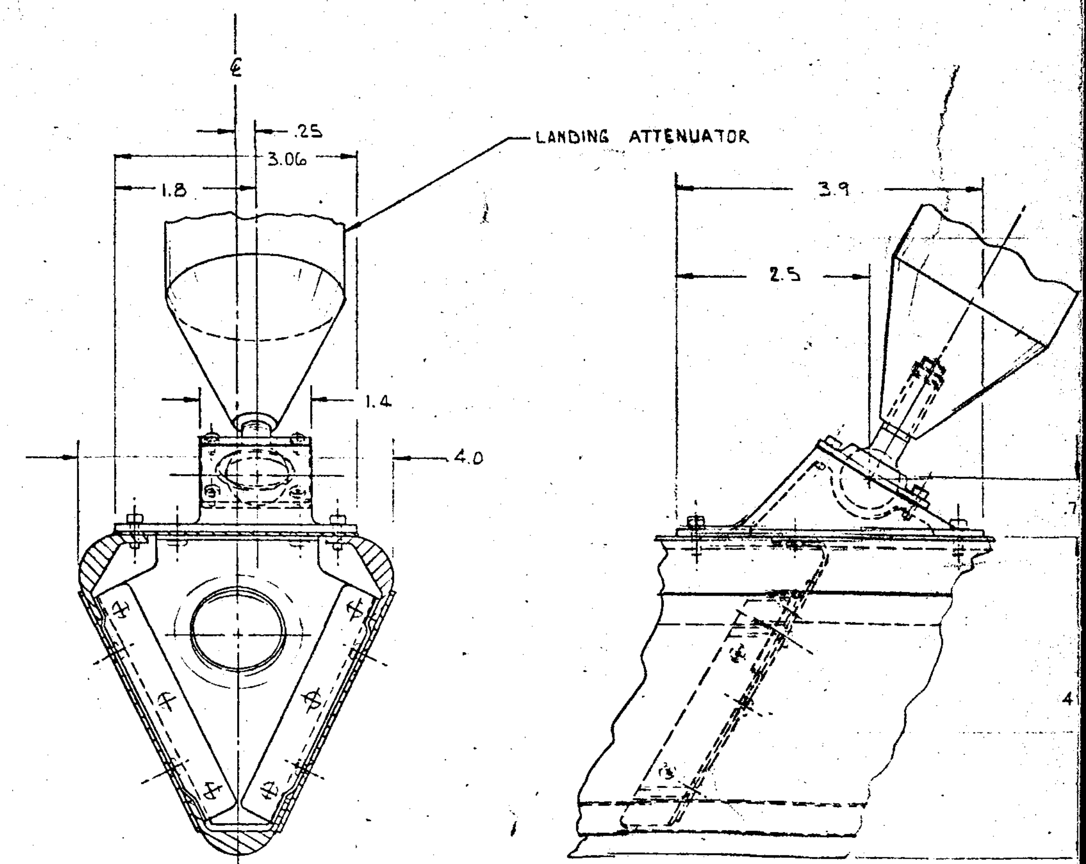



SECTION B - B

SCALE: HALF

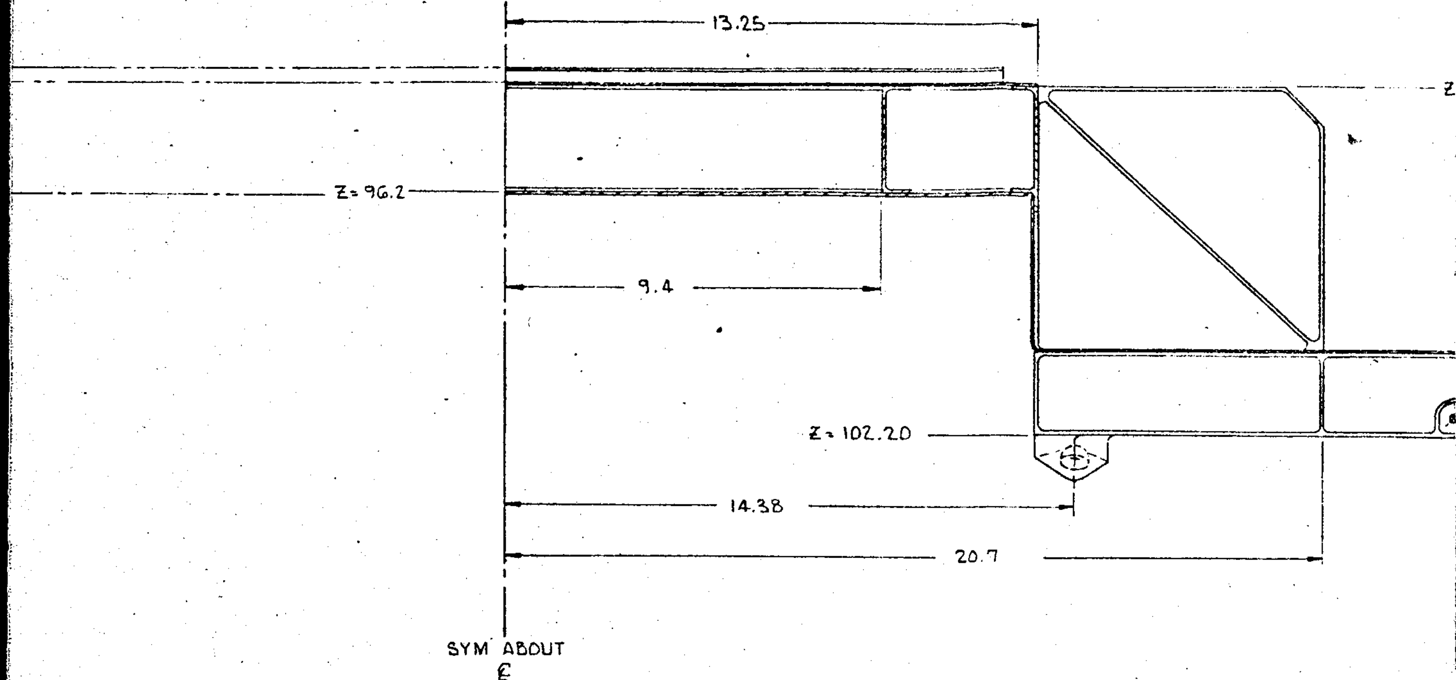
60-1

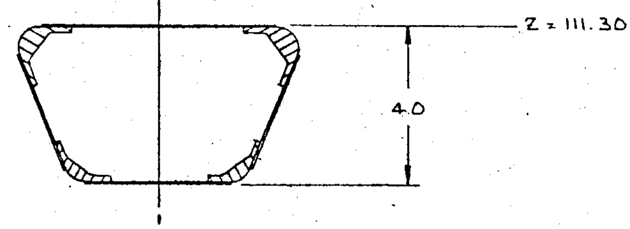



VIEW C
SCALE : FULL

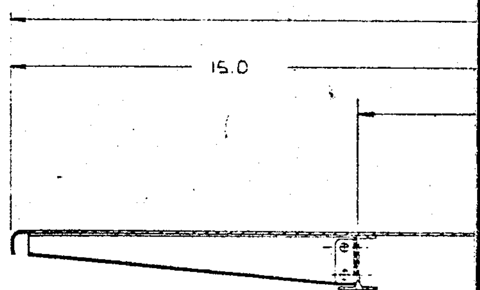
60-2



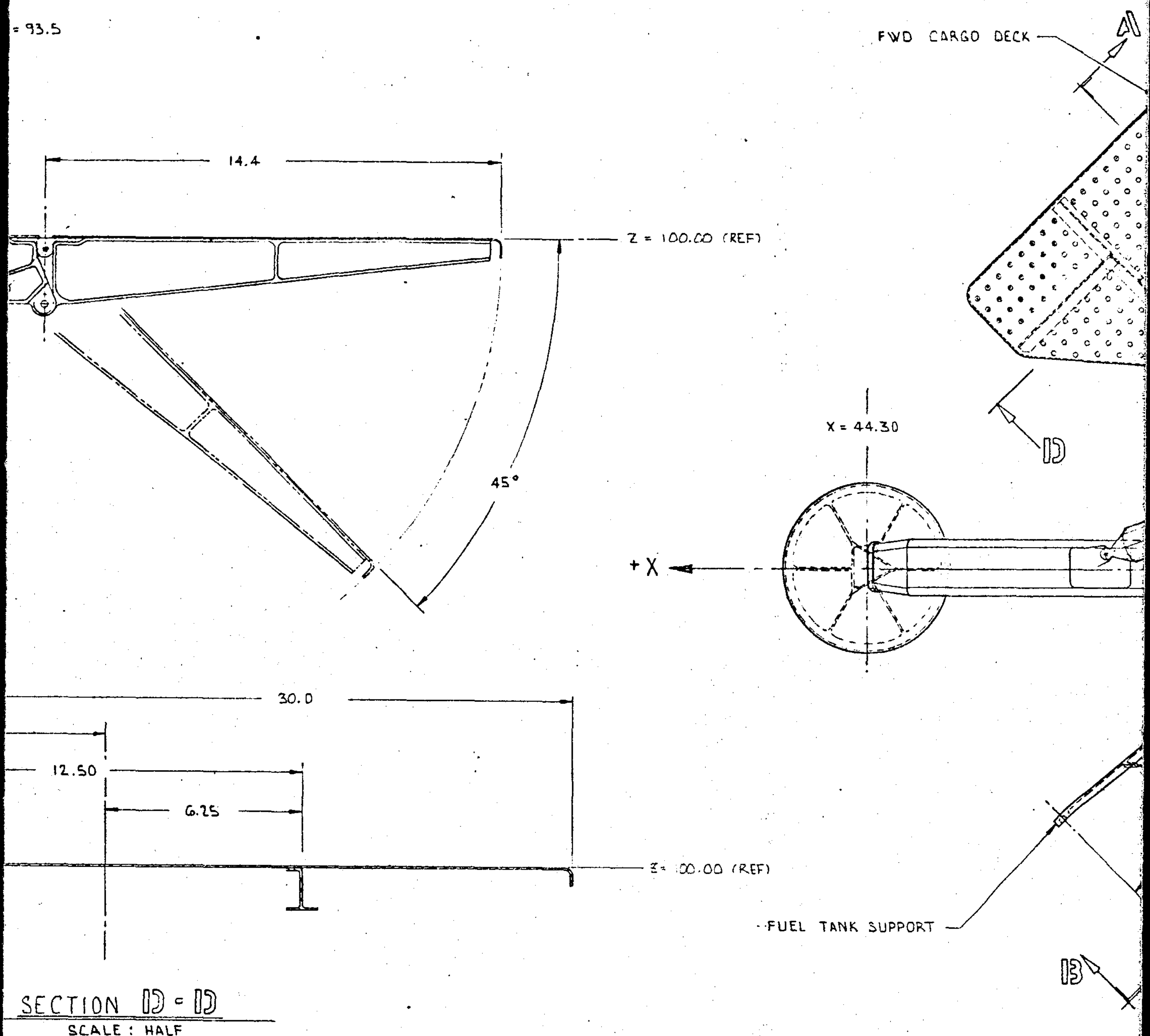




SECTION A-A

SCALE: HALF

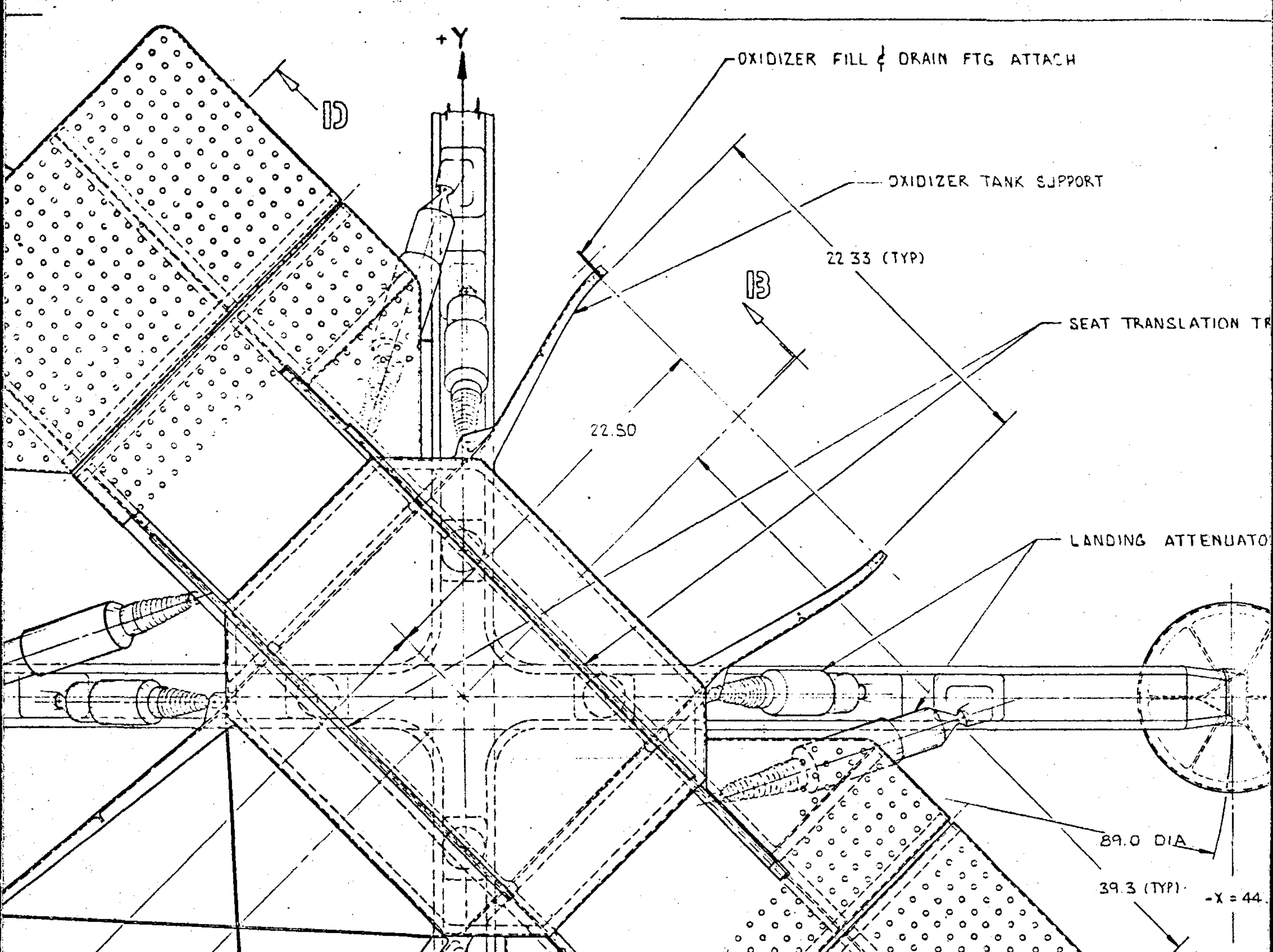



60-3

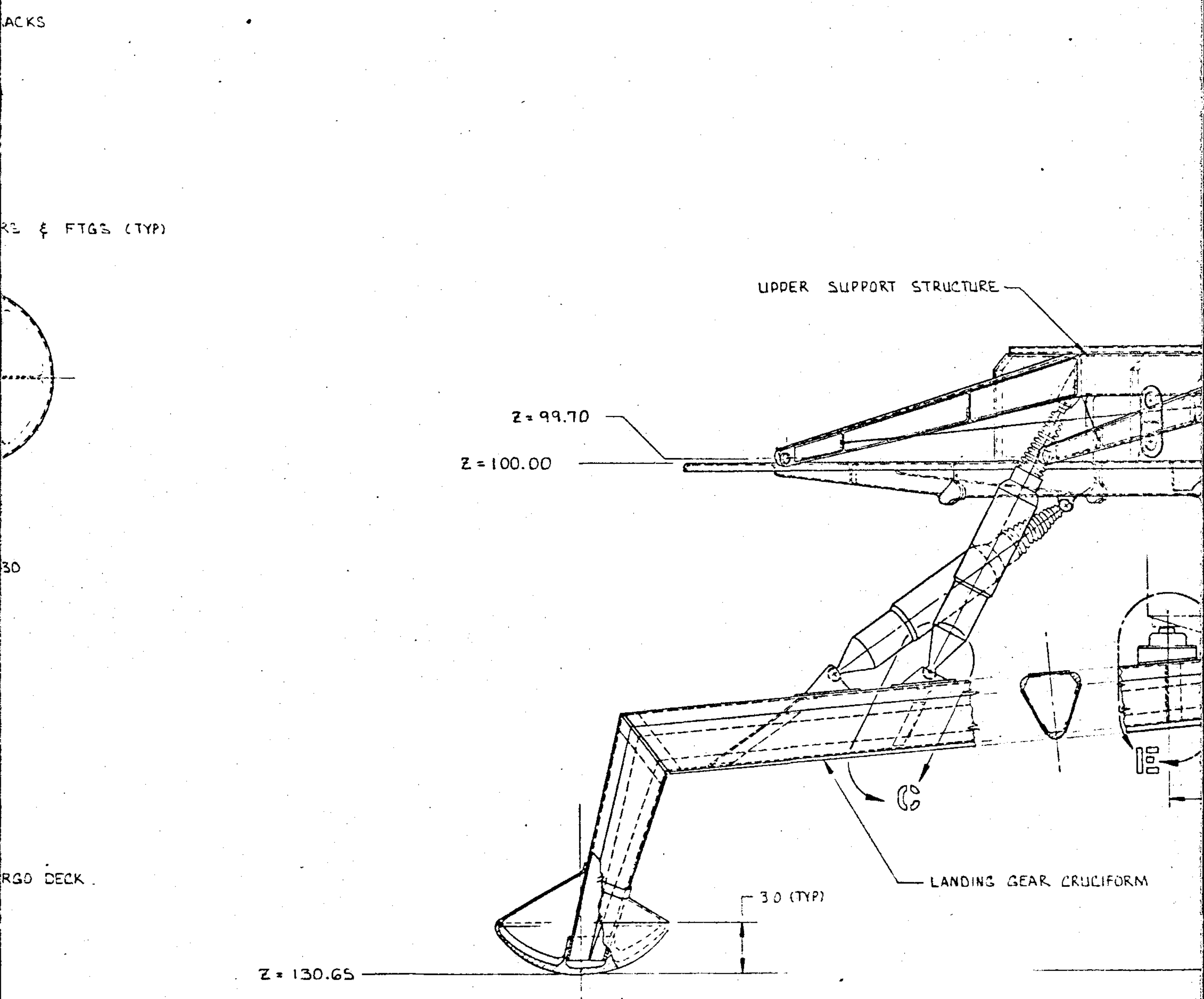


= 93.5
14.4
Z = 100.00 (REF)
45°
30.0
12.50
6.25
Z = 100.00 (REF)
SECTION D - D
SCALE : HALF
FWD CARGO DECK
A
X = 44.30
D
+X
FUEL TANK SUPPORT
B
FUEL FI

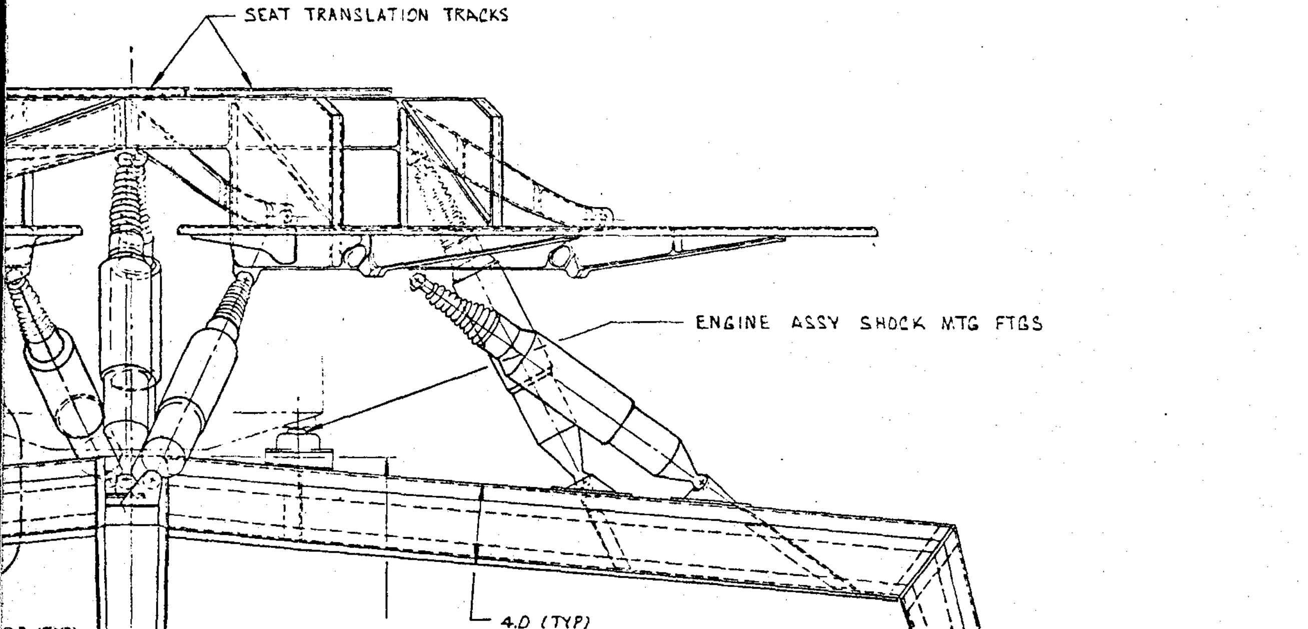

60-4



+Y
D
OXIDIZER FILL & DRAIN FTG ATTACH
OXIDIZER TANK SUPPORT
22.33 (TYP)
B
SEAT TRANSLATION TR
22.50
LANDING ATTENUATO
89.0 DIA
39.3 (TYP)
-X = 44.
33.75
AFT CA
30.0 (TYP)
A
L & DRAIN FTG ATTACH
60-5


ACKS
RS & FTGS (TYP)
30
RGO DECK
UPPER SUPPORT STRUCTURE
Z = 99.70
Z = 100.00
LANDING GEAR CRUCIFORM
3.0 (TYP)
Z = 130.65

60-6


SEAT TRANSLATION TRACKS
ENGINE ASSY SHOCK MTG FTGS
8.5 (TYP)
19.35
4.0 (TYP)
DUST COVER (TYP)

60-7

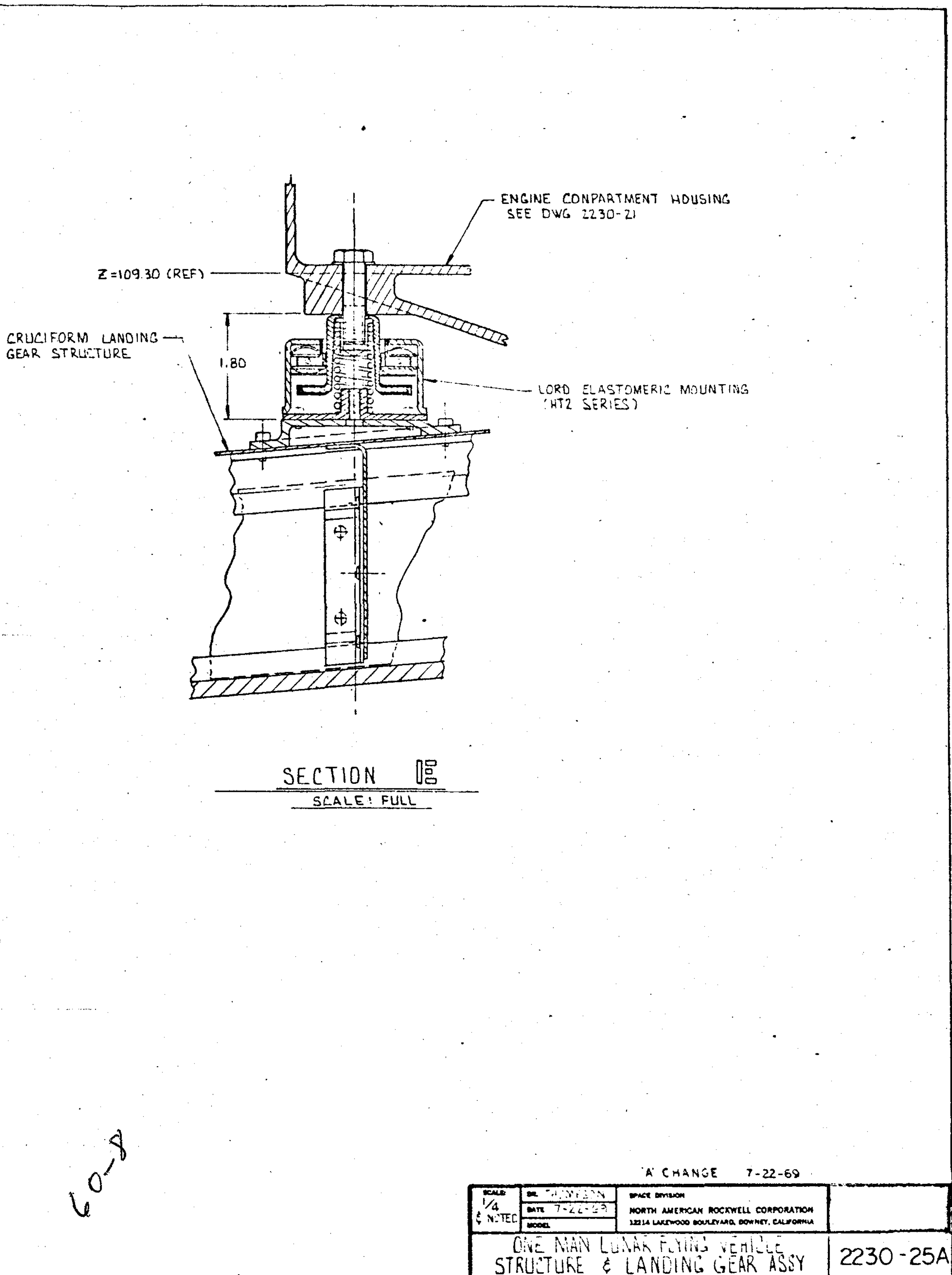
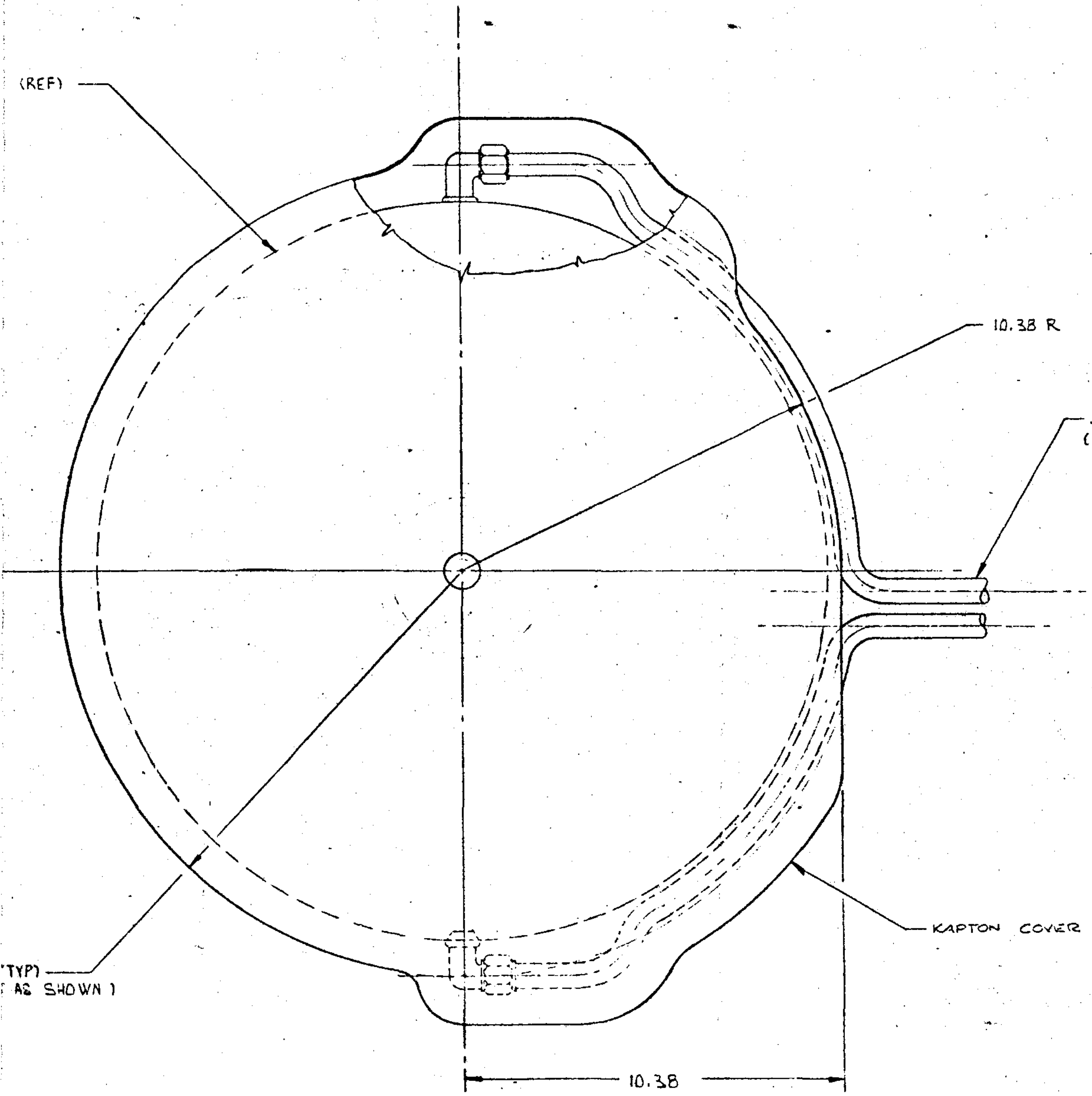



Figure 11. LFV Structure and Landing Gear Assembly (Drawing 2230-25)

2230-103 PRESSURE VESSEL

11.02 R
(EXCEPT

61-1

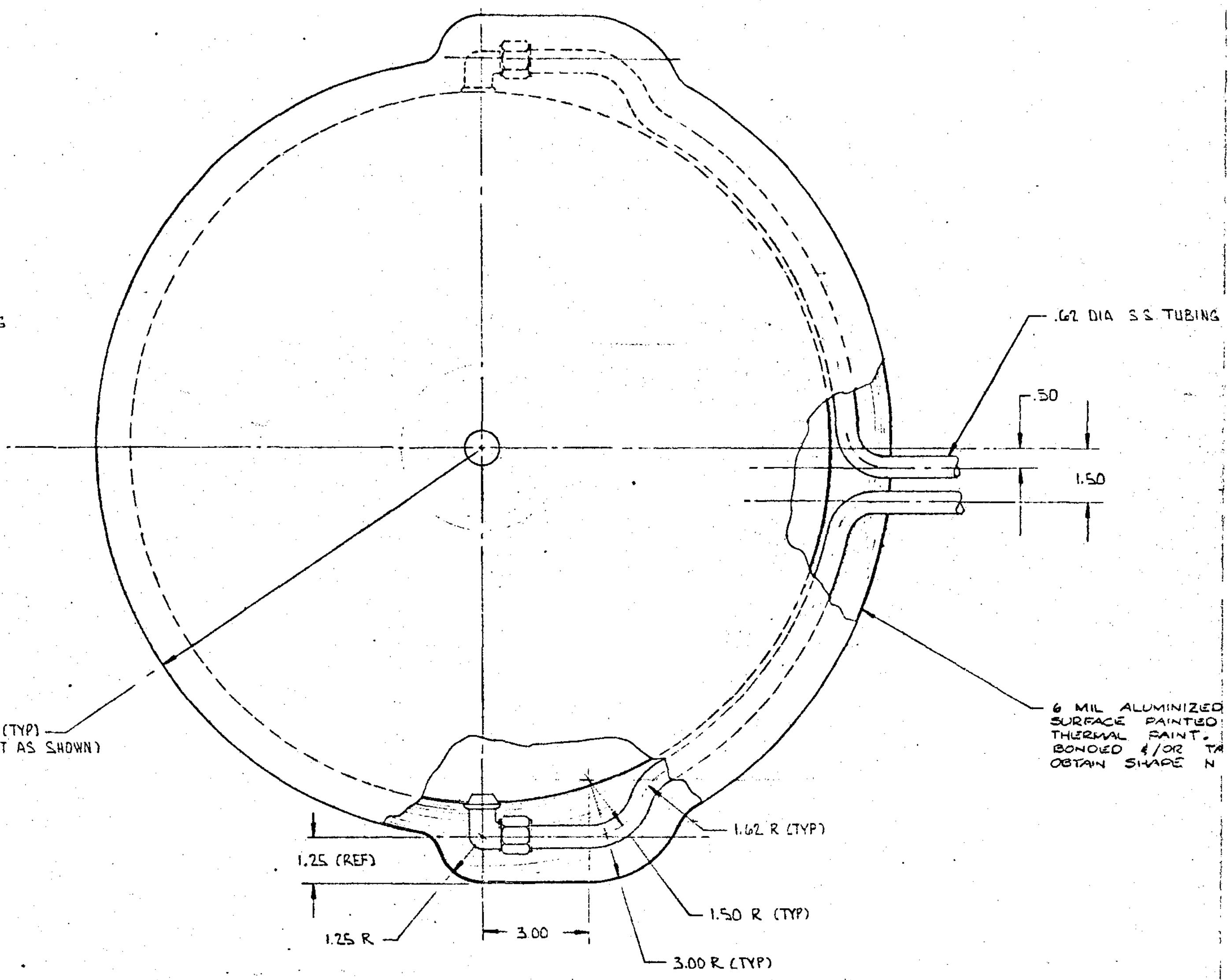



$N_2O_4$ TANK

(IDENTICAL TO AEROZINE 50 TANK EXCEPT AS SHOWN)

61-2

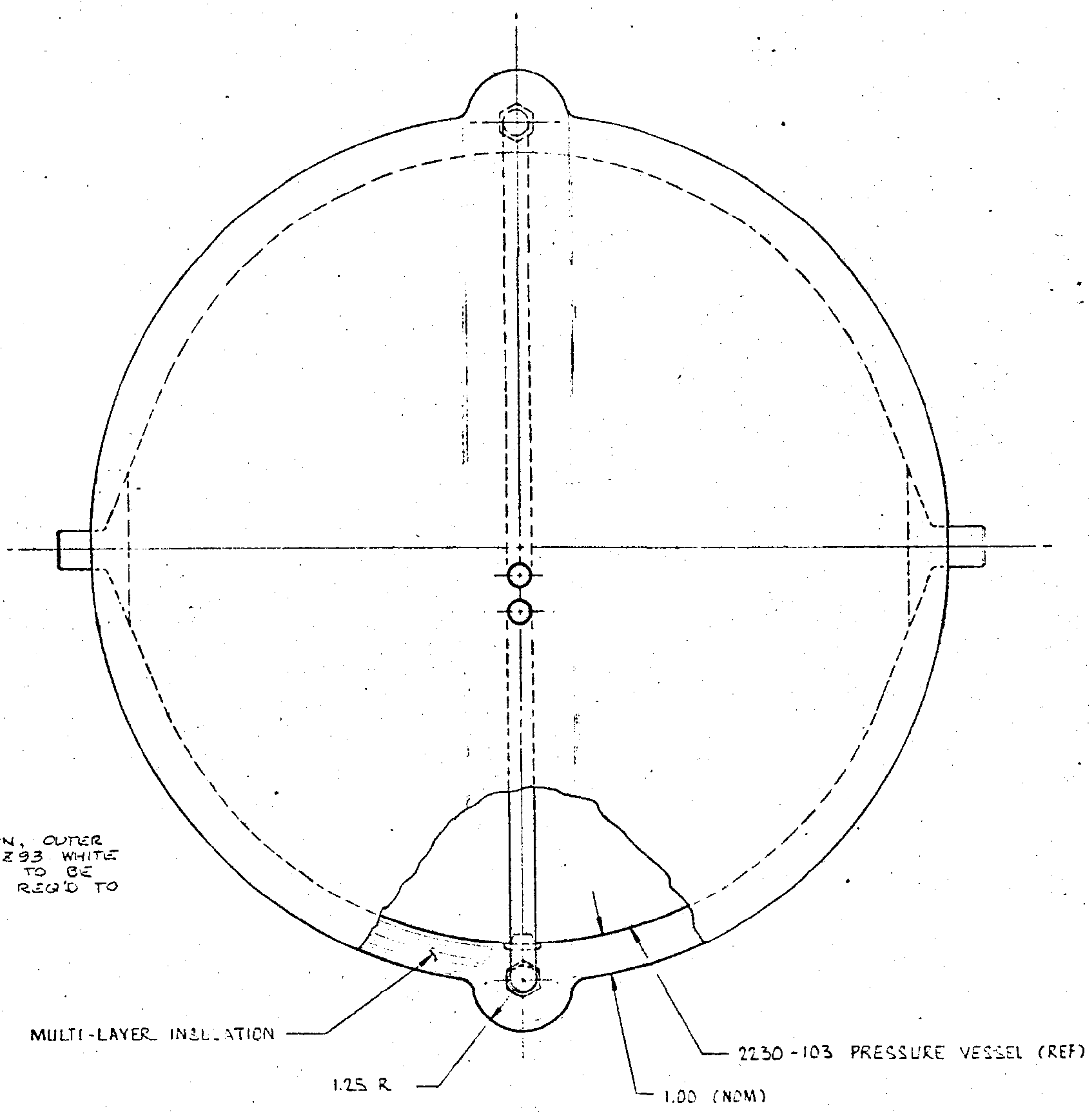
RAWING




AEROZINE 50

61-3

KAPTON, OUTER
WITH Z93 WHITE
KAPTON TO BE
PED AS REQ'D TO
TED




TANK

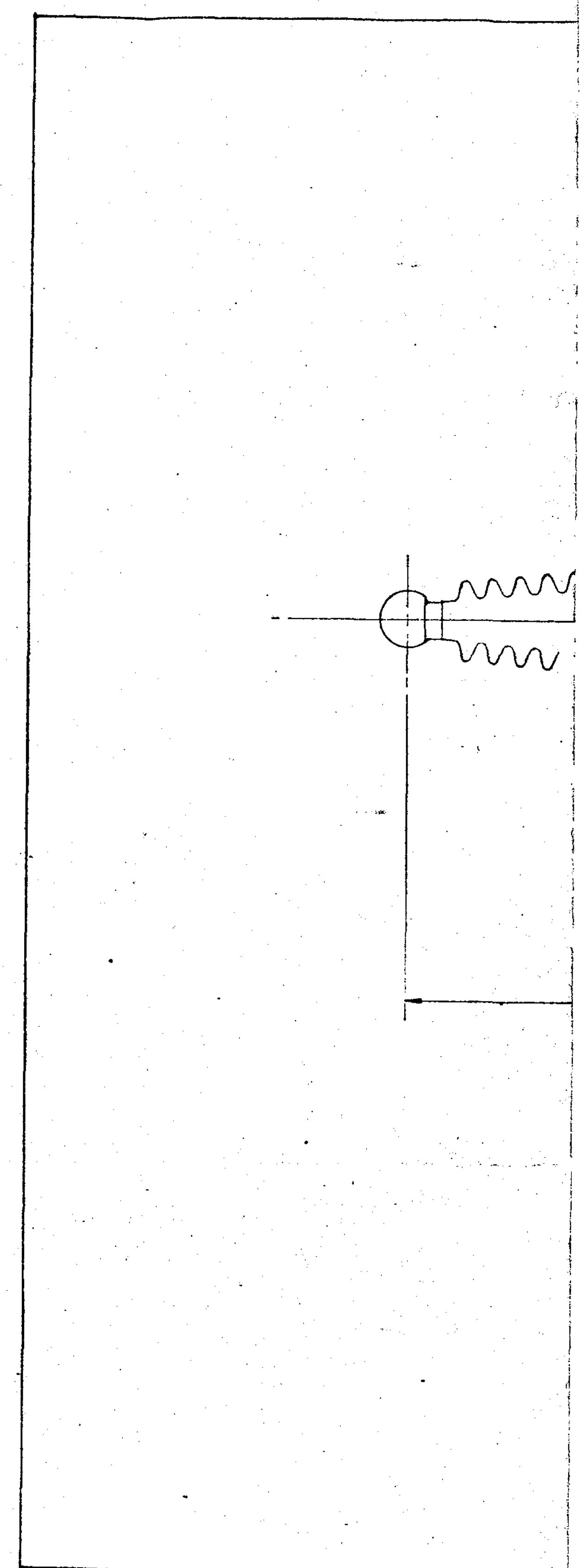
61-4

A 6-25-69 CLW

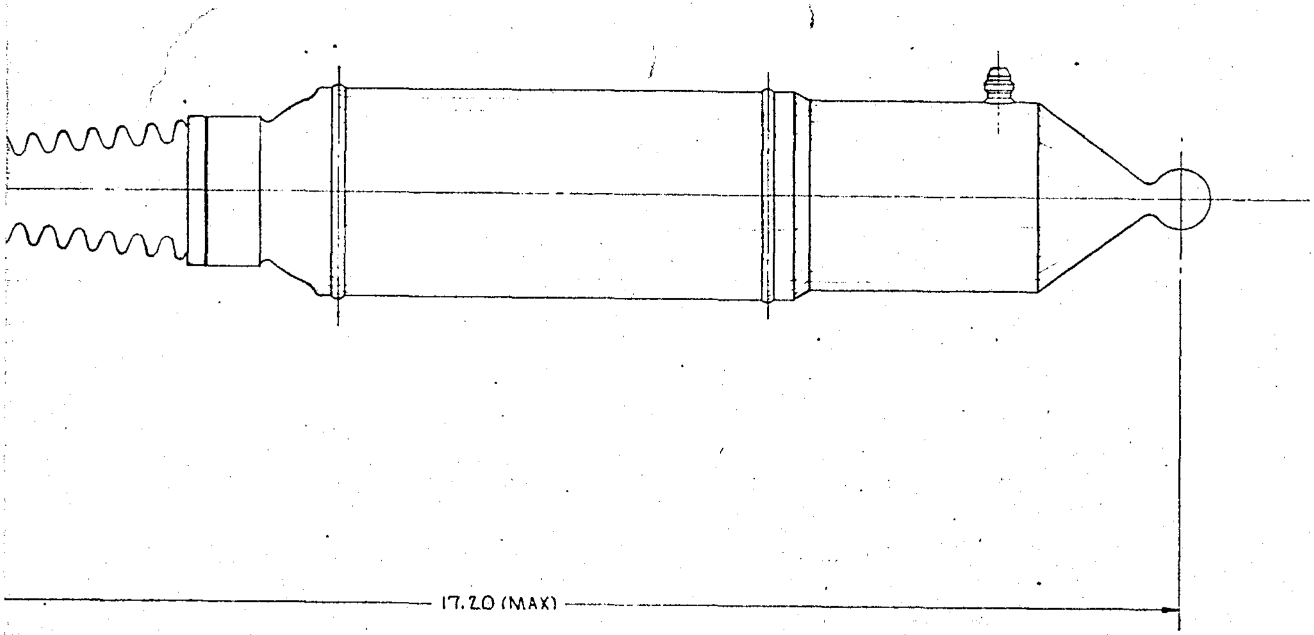
| | | | |
|---|---|---|---|
| SCALE: NOTED | DR. / DATE / MODEL | SPACE DIVISION NORTH AMERICAN ROCKWELL CORPORATION 12214 LAKEWOOD BOULEVARD, DOWNEY, CALIFORNIA | |
| ONE MAN LFV - PROPELLANT TANK INSTALLATION | | | 2230-26A |

61-5

Figure 12. LFV Propellant Tank Installation (Drawing 2230-26)

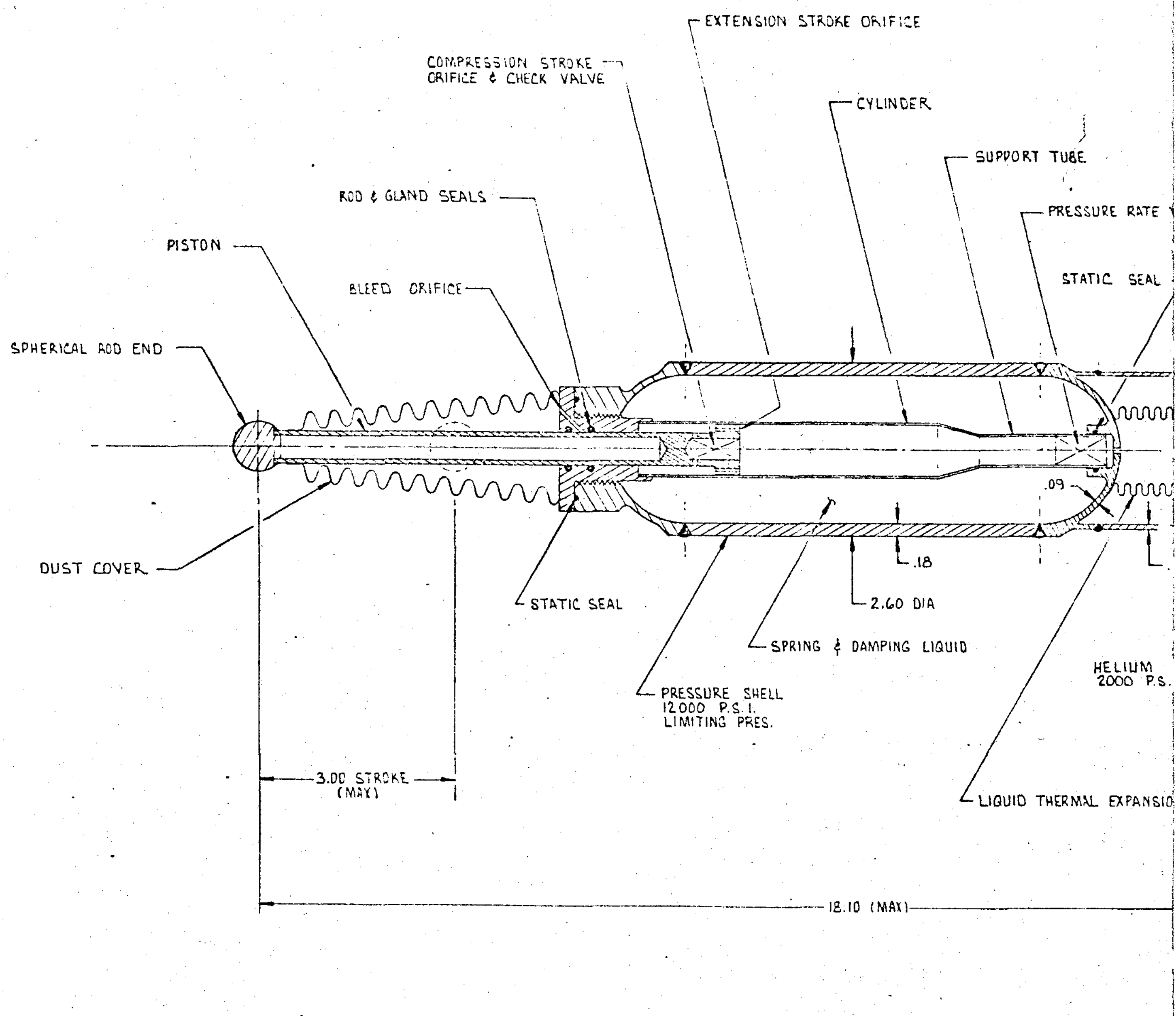


62-1



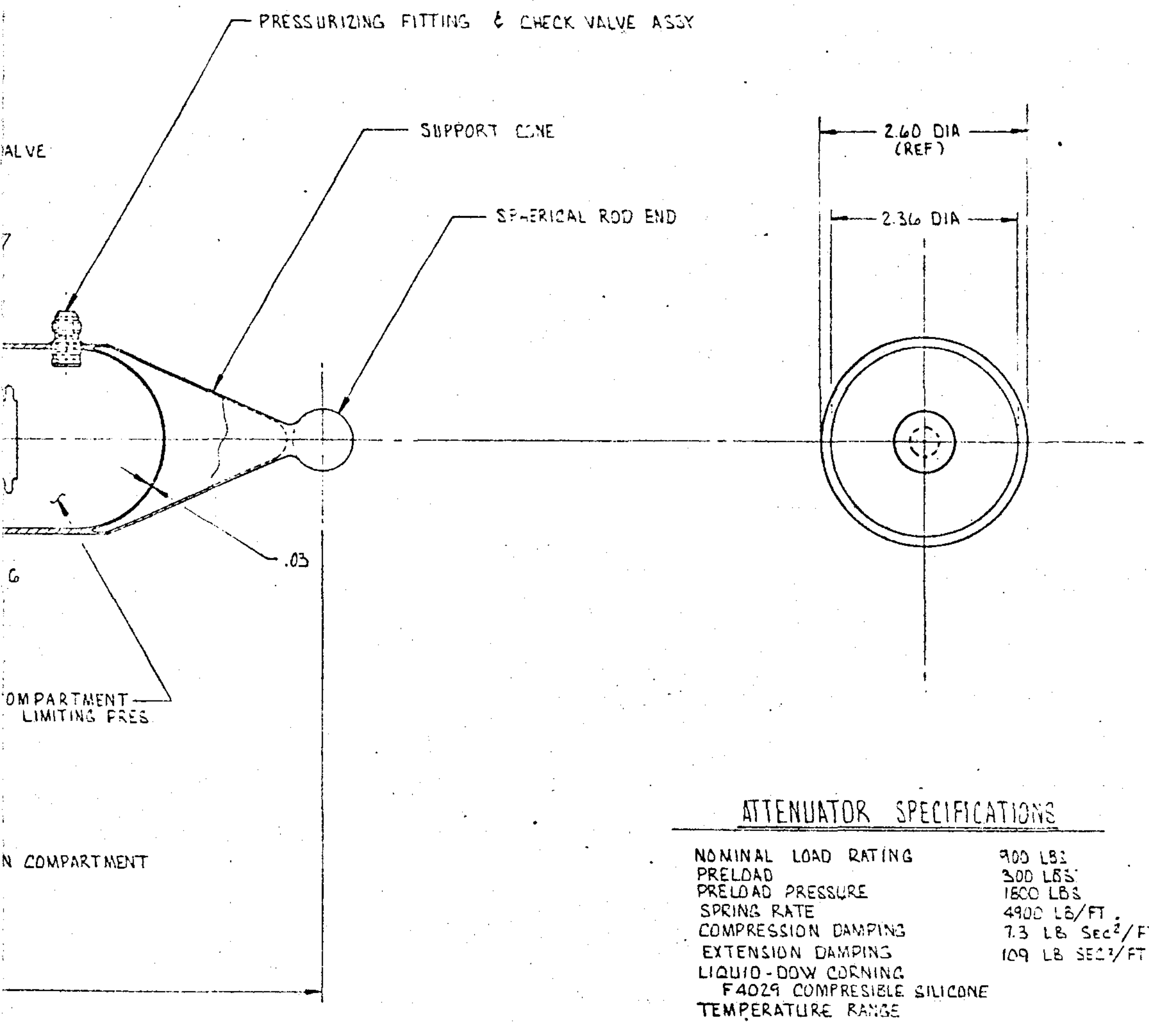

ATTENUATOR - TYPE I
( IDENTICAL TO TYPE II EXCEPT AS SHOWN )
SCALE: FULL

62-2




ATTENUATOR - TYPE II

SCALE: FULL




## ATTENUATOR SPECIFICATIONS

| | |
|---|---|
| NOMINAL LOAD RATING | 900 LBS |
| PRELOAD | 300 LBS |
| PRELOAD PRESSURE | 1600 LBS |
| SPRING RATE | 4900 LB/FT |
| COMPRESSION DAMPING | 7.3 LB $Sec^2/FT^2$ |
| EXTENSION DAMPING | 109 LB $SEC^2/FT^2$ |
| LIQUID - DOW CORNING F4029 COMPRESIBLE SILICONE | |
| TEMPERATURE RANGE | |
| STORAGE | -65° TO 175° F |
| OPERATING | 0° TO 125° F |
| RATED LIFE | 200 CYCLES |

| SCALE | DR. | SPACE DIVISION |
|---|---|---|
| FULL | DATE | NORTH AMERICAN ROCKWELL CORPORATION |
| | MODEL | 12214 LAKEWOOD BOULEVARD, DOWNEY, CALIFORNIA |
| ONE MAN LFV ATTENUATOR CONCEPT | | 223C-27 |

Figure 13. LFV Attenuator Concept (Drawing 2230-27)

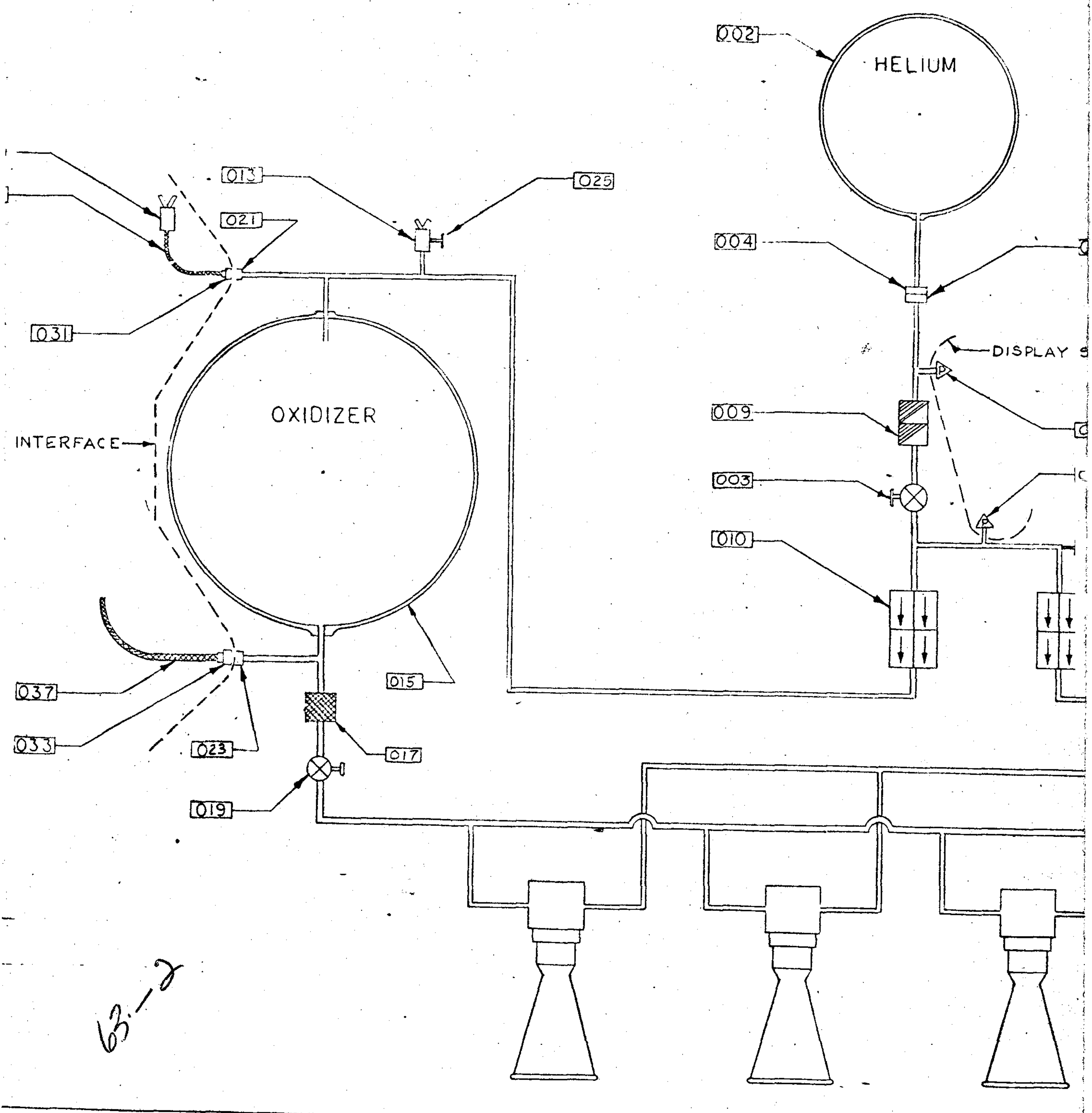
62-5

03

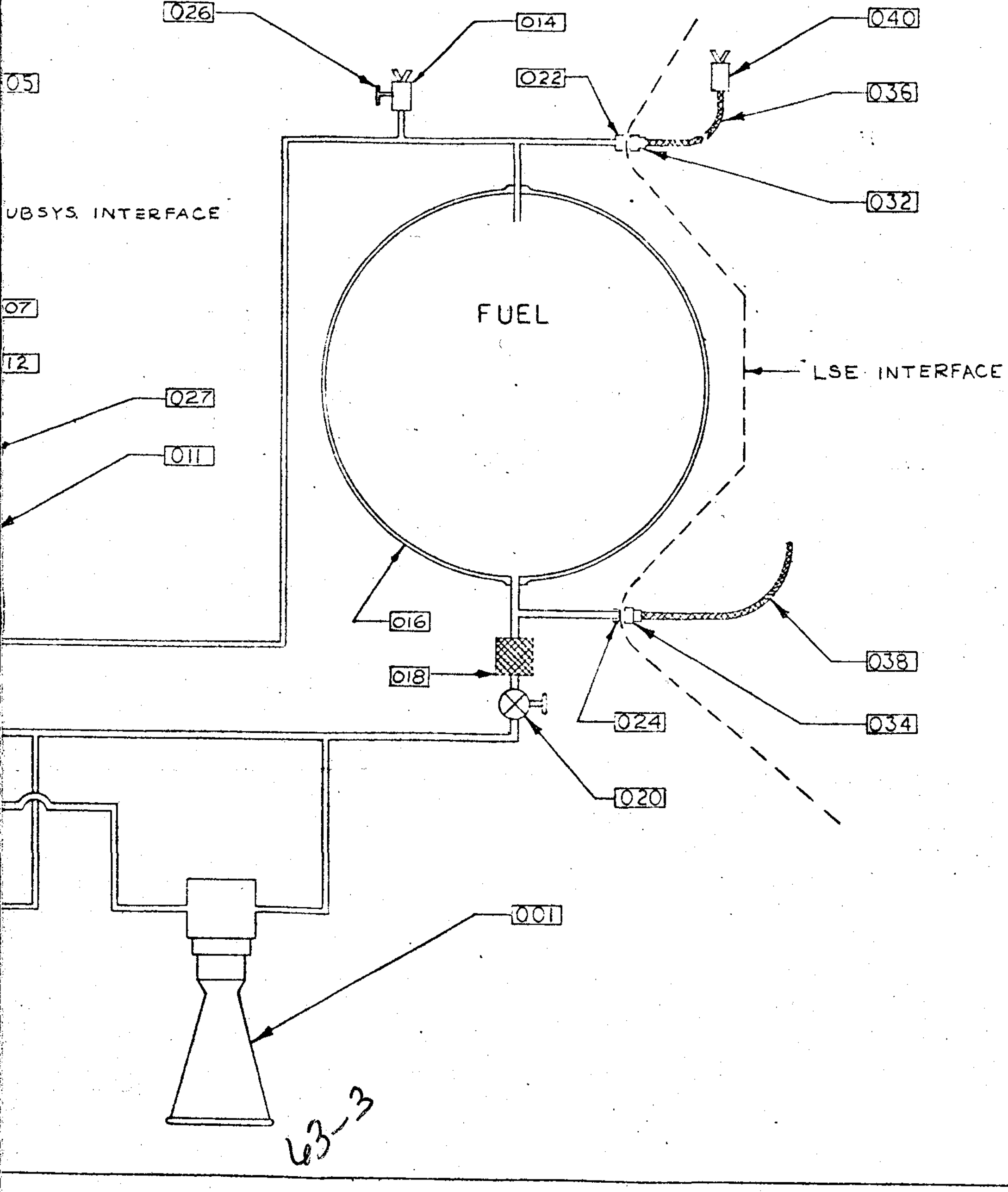
03

LSE

63-1



002
HELIUM
013
025
021
004
031
DISPLAY S
OXIDIZER
009
INTERFACE
003
010
015
037
033
023
017
019
63-2




1 RED
AND

2 RED
AND

NOTE: UNL

Space Division
North American Rockwell

| REVISIONS |
|---|
| A. DELETED VLV. ITEM 006<br>RELOCATED VLV ITEM 003<br>D. L. Babcock<br>5-2-69 |
| B. DELETED ONE AND RELOCATED<br>OTHER PRESS. SENSOR ITEM 012.<br>D L Babcock<br>5-14-69 |
| C. ADDED TEST POINT CPLGS. ITEMS<br>025, 026, 027.<br>INDICATED LSE AND DISPLAY-<br>SUBSYSTEM INTERFACES<br>D L Babcock<br>6-5-69 |

| PART NO | QTY REQD | DESCRIPTION | APOLLO PART NO. |
|---|---|---|---|
| 040 | 1 | VENT RELIEF, FUEL | NEW PART |
| 039 | 1 | VENT RELIEF, OXID. | NEW PART |
| 038 | 1 | FILL HOSE, FUEL | NEW PART |
| 037 | 1 | FILL HOSE, OXID. | NEW PART |
| 036 | 1 | VENT HOSE, FUEL | NEW PART |
| 035 | 1 | VENT HOSE, OXID. | NEW PART |
| 034 | 1 | FILL COUPLING, FUEL GRD. 1/2 | ME 273-0021-0002 1 |
| 033 | 1 | FILL COUPLING, OXIDE GRD. 1/2 | ME 273-0019-0002 1 |
| 032 | 1 | VENT COUPLING, FEUL, GRD. 1/2 | ME 273-0024-0002 1 |
| 031 | 1 | VENT COUPLING, OXID, GRD. 1/2 | ME 273-0011-0002 1 |
| 012 | 1 | PRESS. SENSOR, HE, REG. | |
| 007 | 1 | PRESS SENSOR, HE, HIGH | |
| 024 | 1 | FILL COUPLING. FUEL. LFV 1/2 | ME 273-0021-0001 |
| 023 | 1 | FILL COUPLING. OXID. LFV 1/2 | ME 273-0019-0001 |
| 020 | 1 | MANUAL VALVE, FUEL | NEW PART |
| 019 | 1 | MANUAL VALVE, OXID. | NEW PART |
| 018 | 1 | FILTER, FUEL | ME 286-0039 TYPE |
| 017 | 1 | FILTER, OXIDE | ME 286-0039 TYPE |
| 027 | 1 | TEST POINT COUPLING HELIUM | ME 144-0023-0051 |
| 026 | 1 | TEST POINT COUPLING FUEL | ME 144-0023-0031 |
| 025 | 1 | TEST POINT COUPLING. OXID. | ME 144-0023-0011 |
| 022 | 1 | VENT COUPLING. FUEL. LFV 1/2 | ME 273-0024-0001 |
| 021 | 1 | VENT COUPLING OXIDE.. LFV 1/2 | ME 273-0011-0001 |
| 014 | 1 | RELIEF VALVE FUEL | ME 284-0062-0002 2 |
| 013 | 1 | RELIEF VALVE OXIDE | ME 284-0062-0002 2 |
| 011 | 1 | CHECK VALVE ASSY., FUEL | ME 284-0024-0002 |
| 010 | 1 | CHECK VALVE ASSY., OXID. | ME 284-0024-0001 |
| 009 | 1 | PRESSURE REGULATOR | ME 284-0021-0005 2 |
| 005 | 1 | HELIUM COUPLING, LFV 1/2 | ME 273-0010-0002 1 |
| 003 | 1 | MANUAL VALVE, HELIUM | NEW PART |
| 004 | 1 | HELIUM COUPLING TANK 1/2 | ME 273-0010-0001 |
| 002 | 1 | HELIUM VESSEL | ME 282-0051-0001 |
| 016 | 1 | TANK, FUEL | MAKE FROM 20 GEMINI |
| 015 | 1 | TANK, OXID. | OAMS TANK SHELL |
| 001 | 4 | ENGINE AND GIMBLE | NEW PART |

LIST OF MATERIALS

| SCALE: | DR. F. H. RC-DE<br>DATE 4-24-[illegible]<br>MODEL | SPACE DIVISION<br>NORTH AMERICAN ROCKWELL CORPORATION<br>12214 LAKEWOOD BOULEVARD, DOWNEY, CALIFORNIA |
|---|---|---|

LUNAR FLYING VEHICLE,
PROPULSION SUBSYSTEM
SCHEMATIC

2230-101C

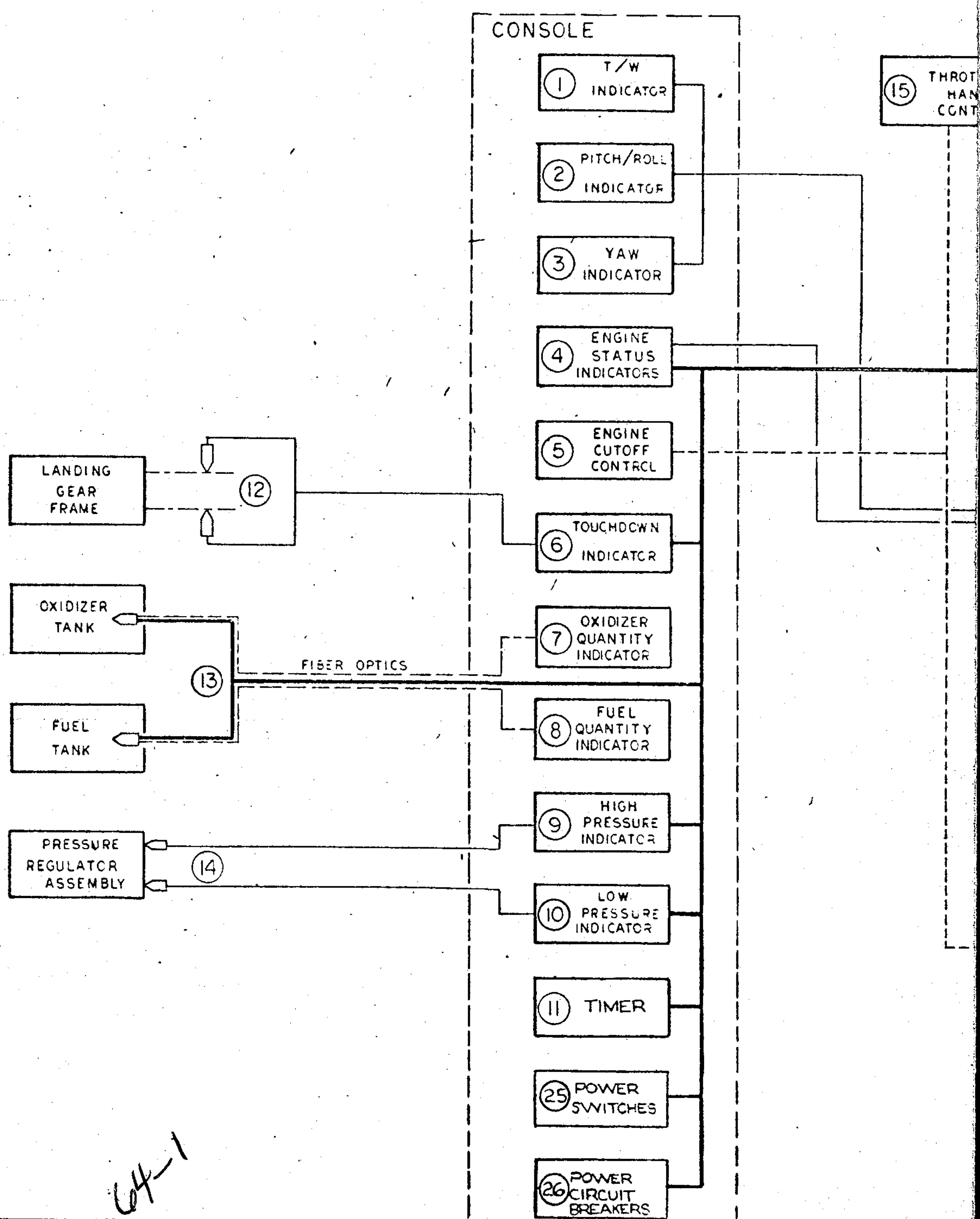
SHEET 1 OF 2

ESIGN FOR PRESSURE SUIT USE
SPACE QUALIFICATION REQUIRED
ESIGN TO NEW SYSTEM PRESSURE
REDESIGNATION MAY BE REQIRED
ESS OTHERWISE SPECIFIED

63-4

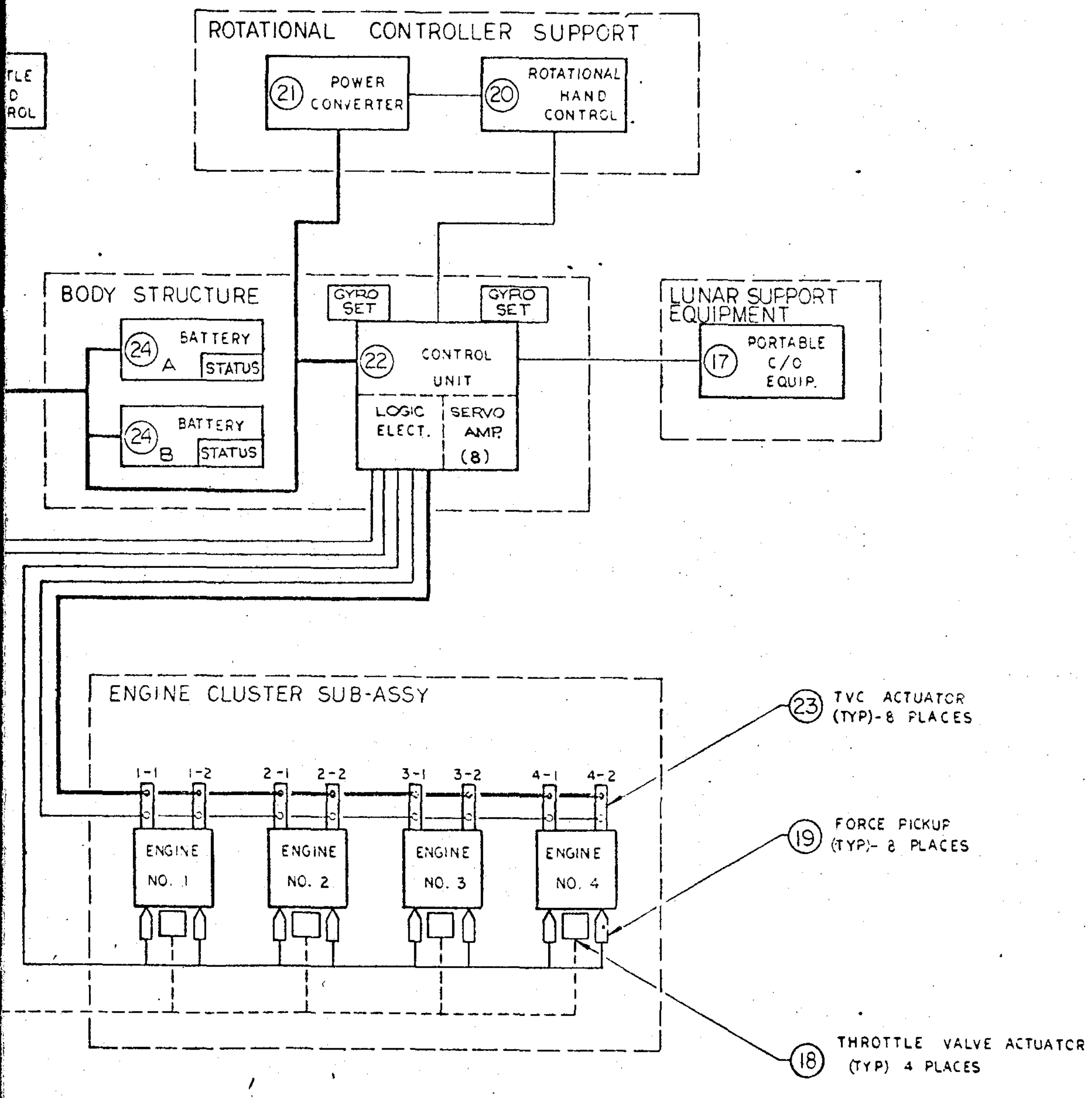
Figure 14. LFV Propulsion Subsystem Schematic (Drawing 2230-101C)

LFV INSTRUMEN
SUBSY




64-1

TATION / CONTROL / POWER
STEM DIAGRAM




64-2

LEGEND

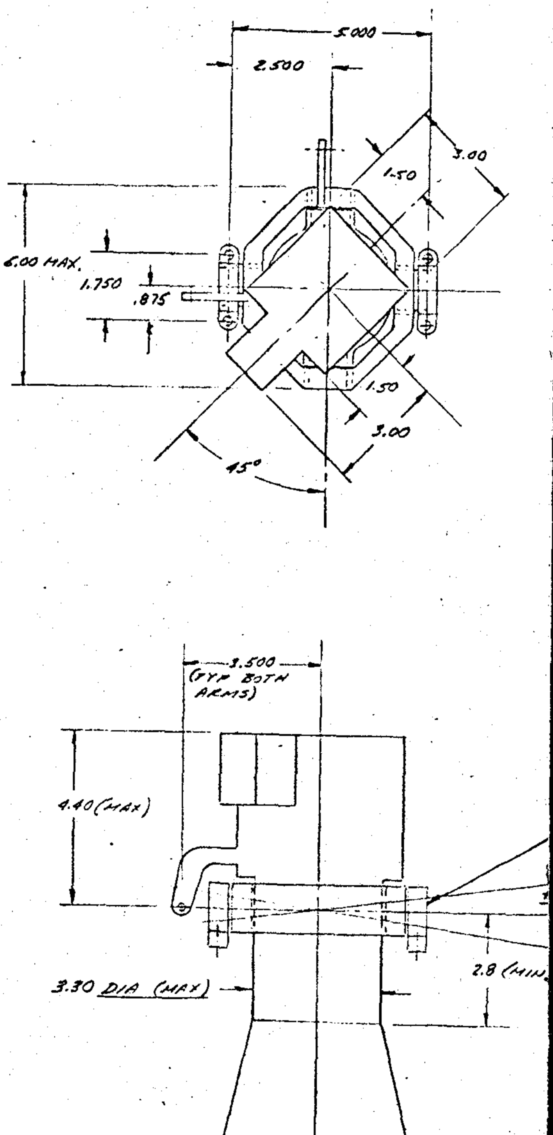
| | |
|---|---|
| ◁ ——— | SENSOR |
| ——— | SIGNAL CIRCUIT |
| ━━━ | POWER CIRCUIT |
| - - - - | MECHANICAL |
| — — | REFERENCED LOCATION |

"B" 8-5-69
7/31/69

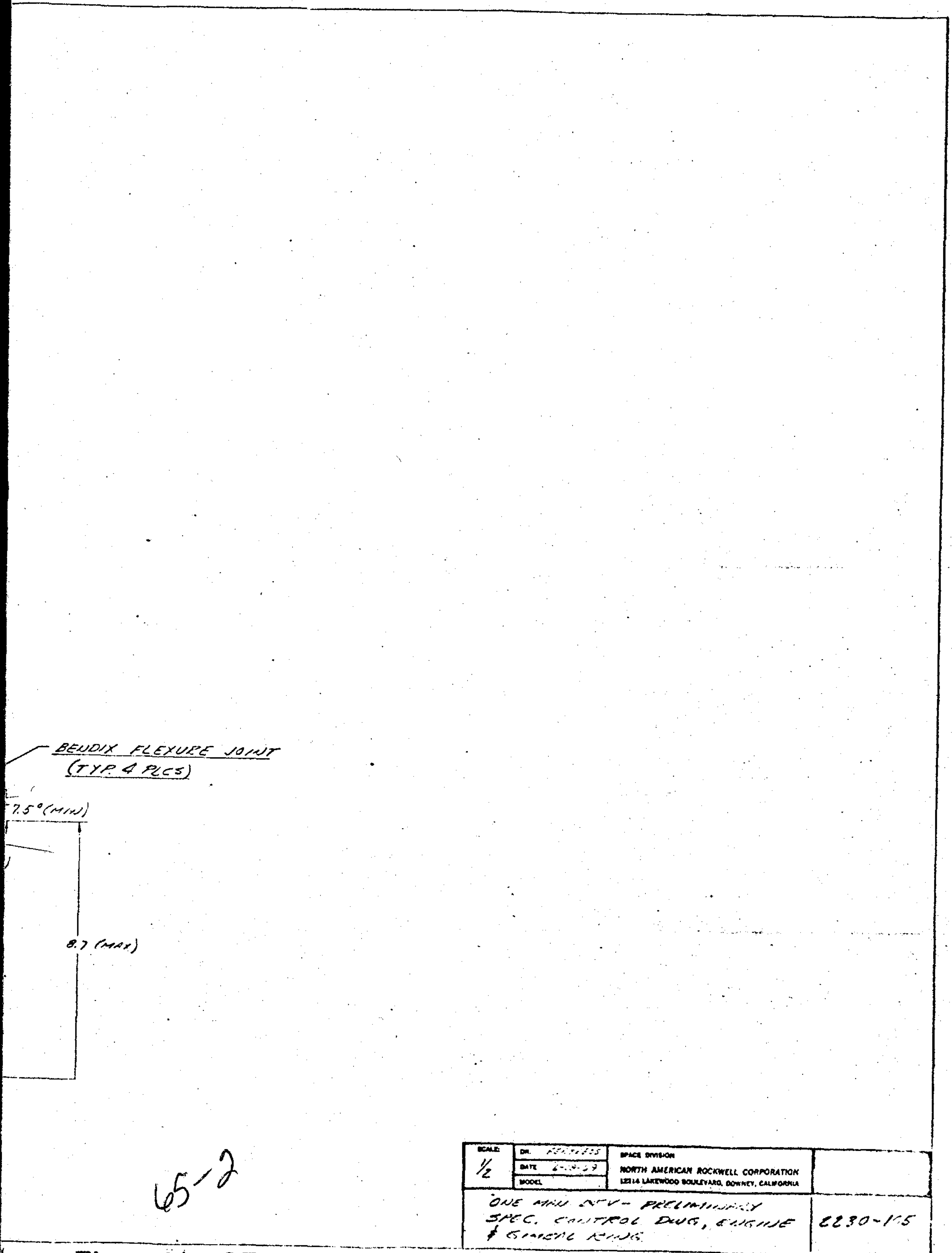
| | | |
|---|---|---|
| SCALE: | DR. THOMPSON | SPACE DIVISION |
| | DATE 6-15-69 | NORTH AMERICAN ROCKWELL CORPORATION |
| | MODEL | 12214 LAKEWOOD BOULEVARD, DOWNEY, CALIFORNIA |
| LFV INSTRUMENTATION - CONTROL POWER SUBSYSTEM DIAGRAM | | 2230-104B |

64-3

Figure 15. LFV Instrumentation, Control, and Power Subsystem Diagram (Drawing 2230-104)

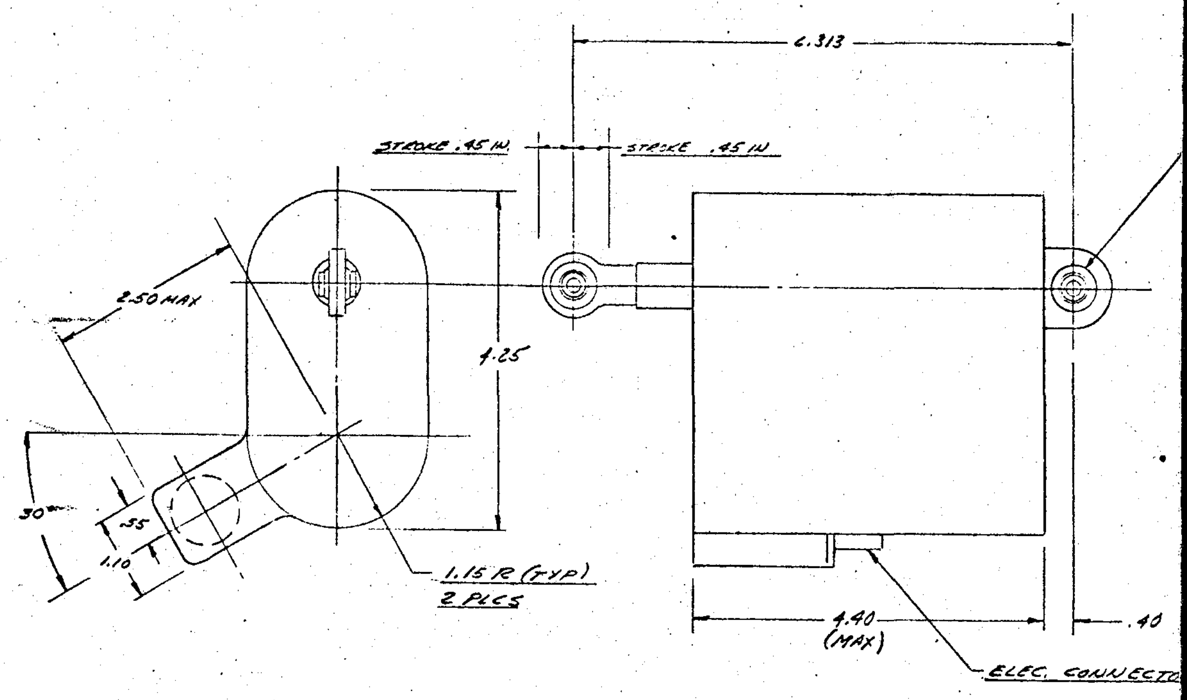

5.000
2.500
3.00
1.50
6.00 MAX.
1.750
.875
1.50
3.00
45°
3.500 (TYP BOTH ARMS)
4.40 (MAX)
3.30 DIA (MAX)
2.8 (MIN
5.90 DIA (MAX)

65-1




65-2

Figure 16. LFV Preliminary Specification Control Drawing, Engine and Gimbal Ring (Drawing 2230-105)



6.313
STROKE .45 IN.
STROKE .45 IN
2.50 MAX
4.25
30°
.55
1.10
1.15 R (TYP)
2 PLCS
4.40
(MAX)
.40
ELEC. CONNECTO


66-1

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North American Rockwell

SELF-ALIGNING BEARING
2 PLCS

e

66-2

| | | | |
|---|---|---|---|
| SCALE FULL | DR. FENTRESS<br>DATE 6-18-69<br>MODEL | SPACE DIVISION<br>NORTH AMERICAN ROCKWELL CORPORATION<br>12214 LAKEWOOD BOULEVARD, DOWNEY, CALIFORNIA | |
| ONE MAN LFV - PRELIMINARY SPEC CONTROL DWG., ELEC. GIMBAL ACTUATOR | | | 2230-107 |

Figure 17. LFV Preliminary Specification Control Drawing, Electrical Gimbal Actuator (Drawing 2230-107)

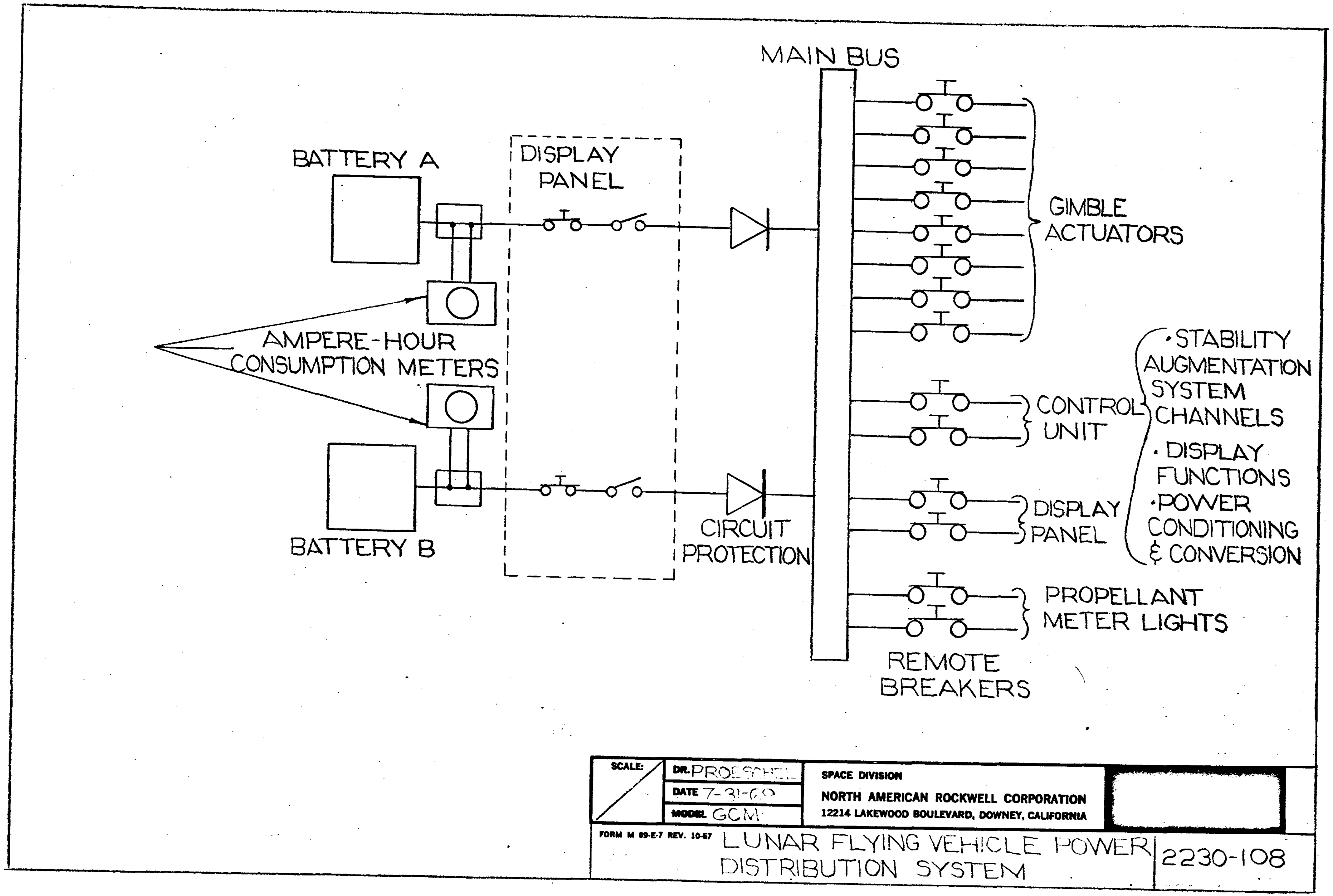


Figure 18. LFV Power Distribution System (Drawing 2230-108)